



The University of Electro-Communications



Spectrum Shared Wireless Sensor Networks based on Radio Environment Database

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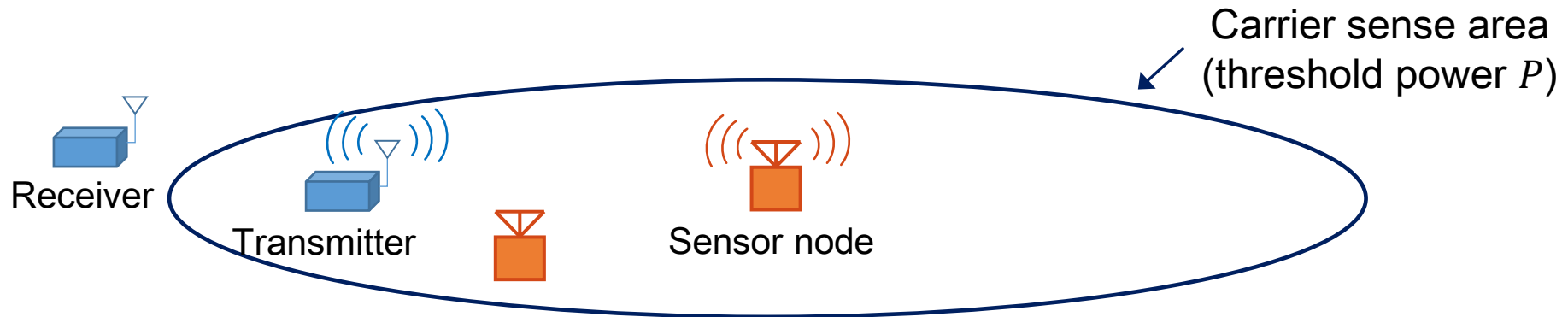
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- Current spectrum allocation in Wireless communications
 - License band : Only license user use band.
 - Shared band : Multiple systems use the same band.
 - ✓ ISM band is unlicensed band on 2.4GHz band.
 - ✓ Multiple applications: Wireless LAN, Wireless sensor networks

- In a shared band, a node needs to avoid interference to other nodes.
 - To avoid interference, CSMA/CA(Carrier Sense Multiple Access/Collision Avoidance) is used.
 - ✓ CSMA/CA is signal collision avoidance method.
 - ✓ By carrier sense, a node knows communication condition of surrounding nodes.

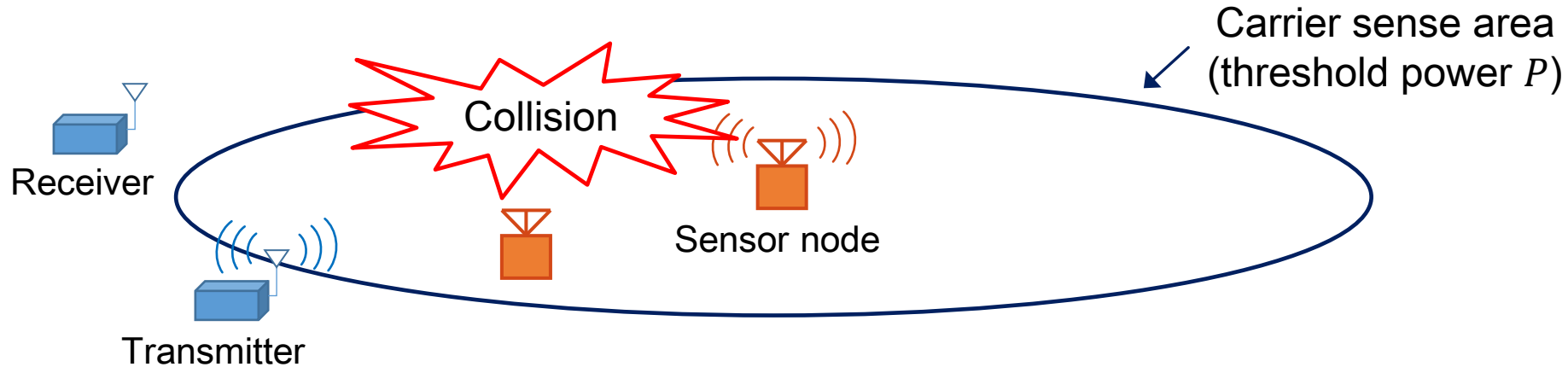
■ CSMA/CA

- If the sensor node wants to transmit to the other node, the node senses the band condition.
 - ✓ If the received power of the sensor node $>$ threshold power P , the node regards surrounding nodes are transmitting.
 - the sensor node does not transmit a signal.
 - ✓ If the received power of the sensor node $<$ threshold power P , the node estimates that surrounding nodes are not transmitting.
 - the sensor node transmits a signal.



■ Hidden Node Problem(HNP)

- The sensor node does not work carrier sense for another node located at far away.



- Packet error is happened by signal collision.

In some channels, we have to select the channel is not caused HNP.

■ Spectrum Shared Wireless Sensor Networks based on Radio Environment Database

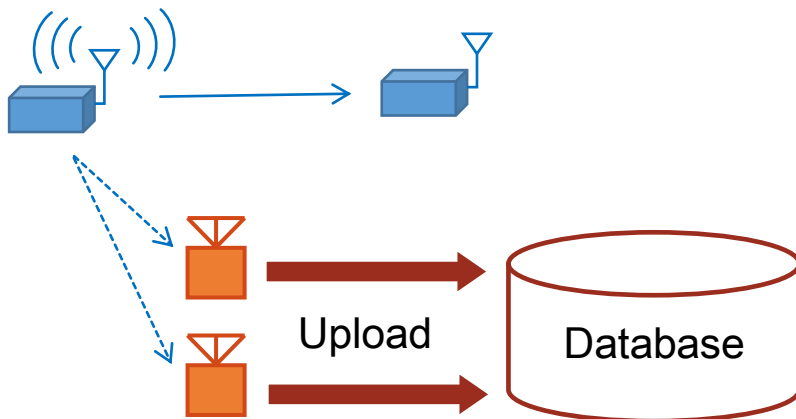
- Purpose :

- ✓ Detection of HNP and using the channel avoiding HNP
- ✓ Improvement of spectrum efficiency

- Proposed method is consist of two phases.

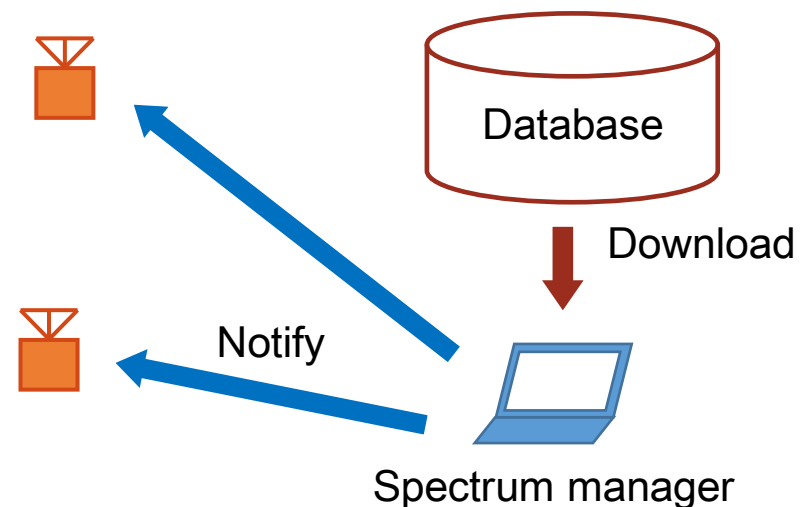
- Phase 1: Database construction.

- ✓ Sensor nodes gather surrounding radio information and upload it to the Database.

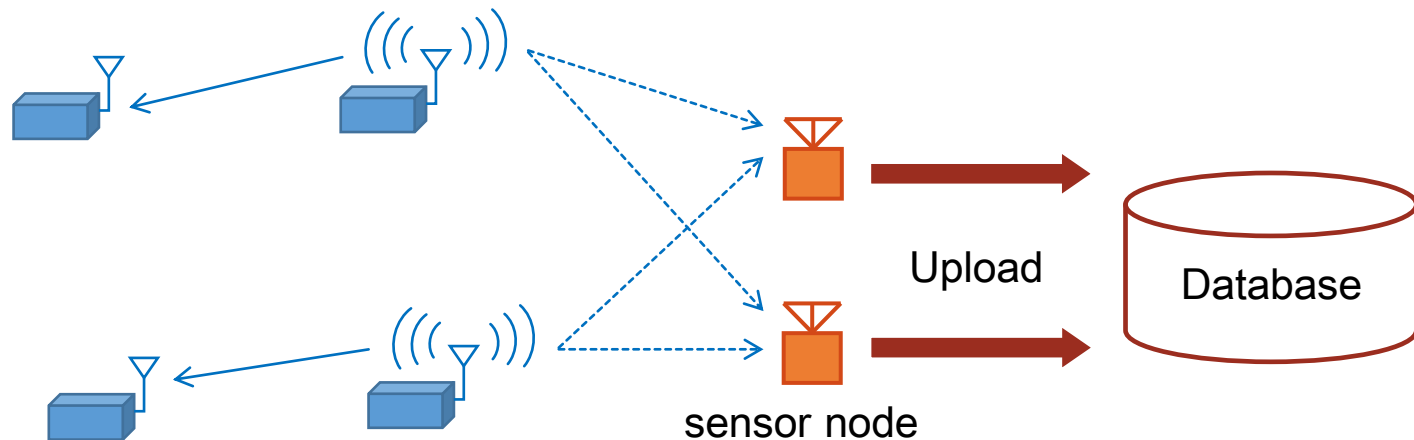


- Phase 2: Database utilization.

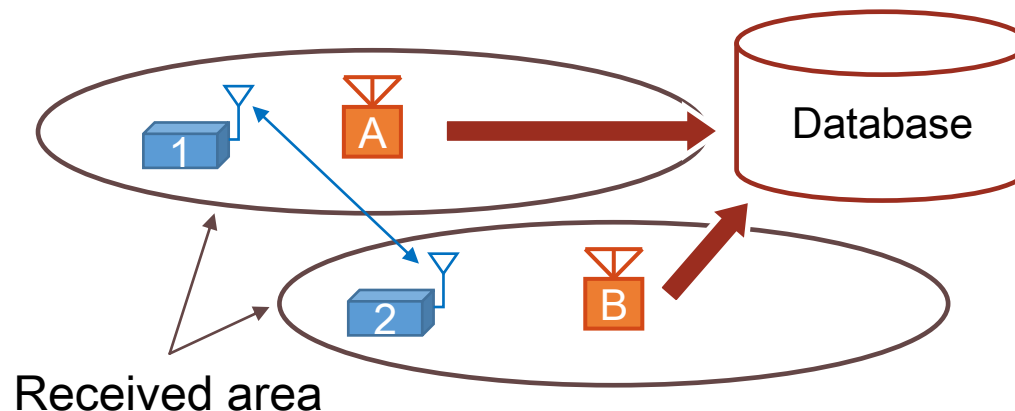
- ✓ The spectrum manager notifies the channel based on the Database information.



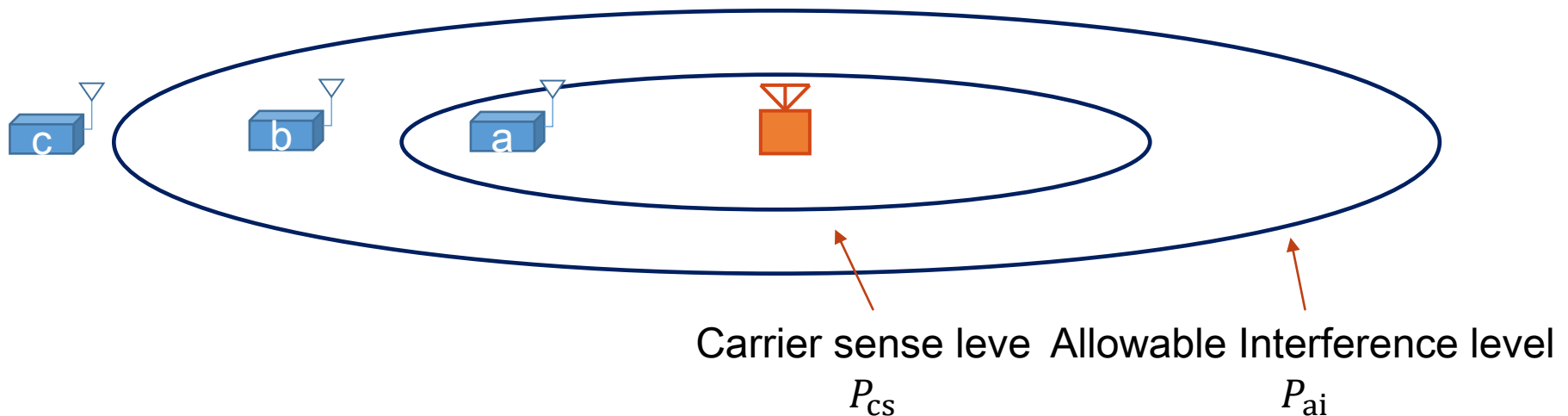
- Sensor nodes gather surrounding radio information and upload them to the Database.
 - Each sensor node analyzes received signal and uploads it to the database.
 - ✓ These sensor nodes use software radio.
 - ✓ Physical layer information(received power, frequency) and MAC layer information(destination/source MAC address) are stored.



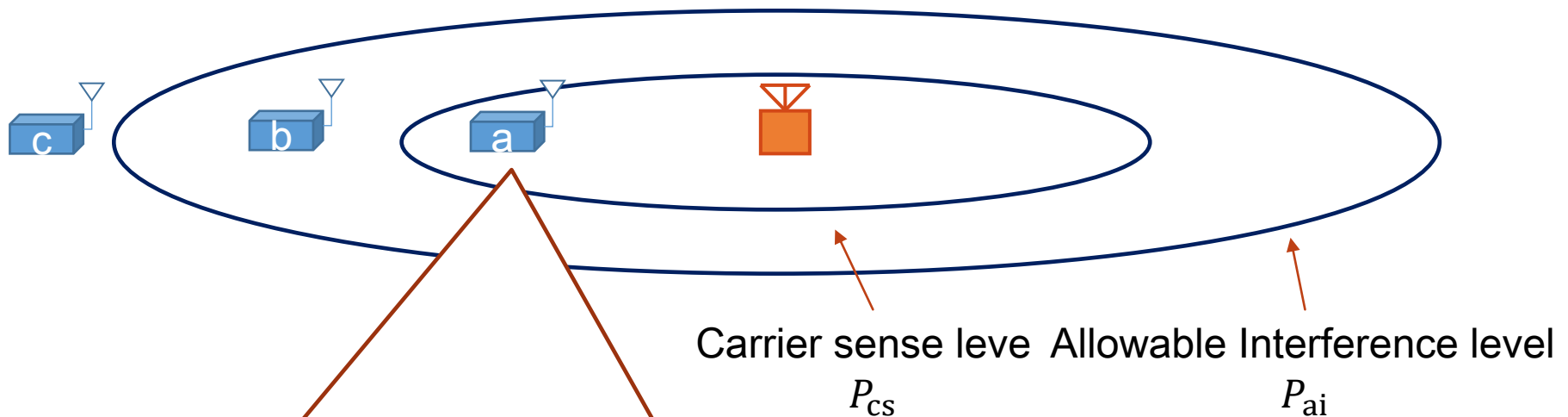
- The database stores several information.
 1. Sensor node ID of itself.
 2. Source's MAC address of observation signal.
 3. Destination's MAC address of observation signal.
 4. Center frequency of observation signal.
 5. Instantaneous received power of observation signal.
- In order to utilize data for all nodes, this information is needed to be statistical data.
- The surrounding radio environment of sensor nodes is shown.



- The spectrum manager selects the channel to avoid HNP and notifies the channel to sensor nodes.
 - First, the spectrum manager categorizes surrounding nodes of sensor nodes based on average received power P in the database.



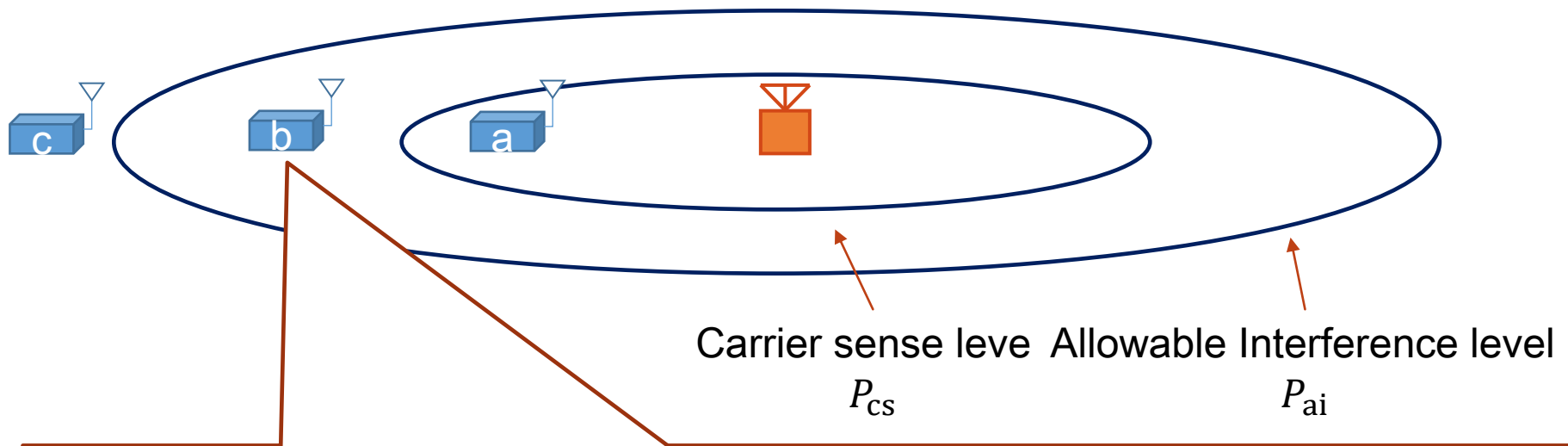
- The spectrum manager selects the channel to avoid HNP and notifies the channel to sensor nodes.
 - First, the spectrum manager categorizes surrounding nodes of sensor nodes based on average received power P in the database.



a. $P > P_{cs}$

- This node is detected by carrier sense of the sensor node.

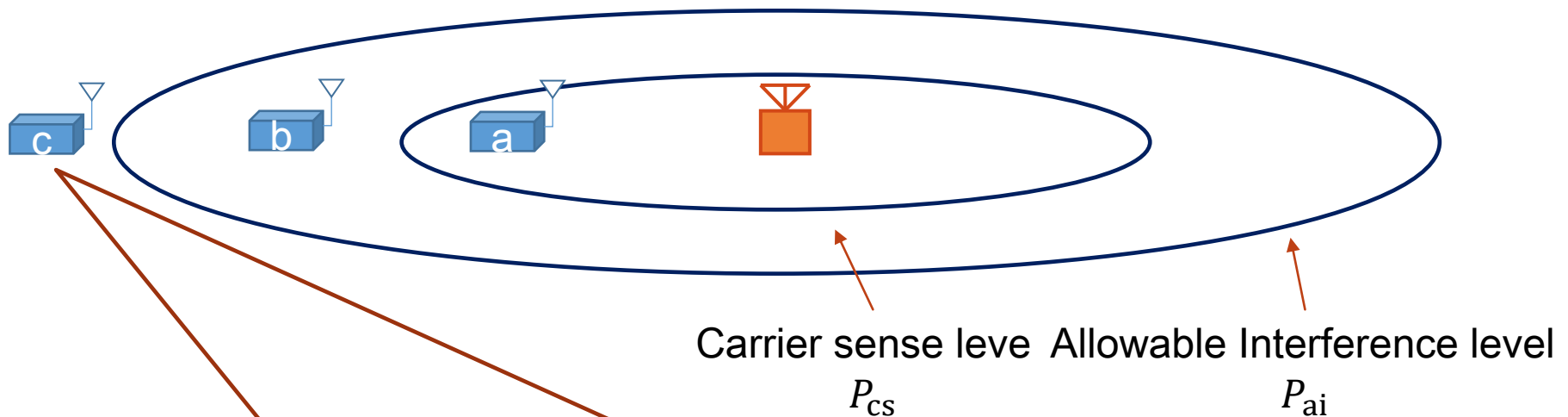
- The spectrum manager selects the channel to avoid HNP and notifies the channel to sensor nodes.
 - First, the spectrum manager categorizes surrounding nodes of sensor nodes based on average received power P in the database.



b. $P_{cs} > P > P_{ai}$

- This node is not detected by carrier sense of the sensor node
- This node gives interference to the sensor node.

- The spectrum manager selects the channel to avoid HNP and notifies the channel to sensor nodes.
 - First, the spectrum manager categorizes surrounding nodes of sensor nodes based on average received power P in the database.

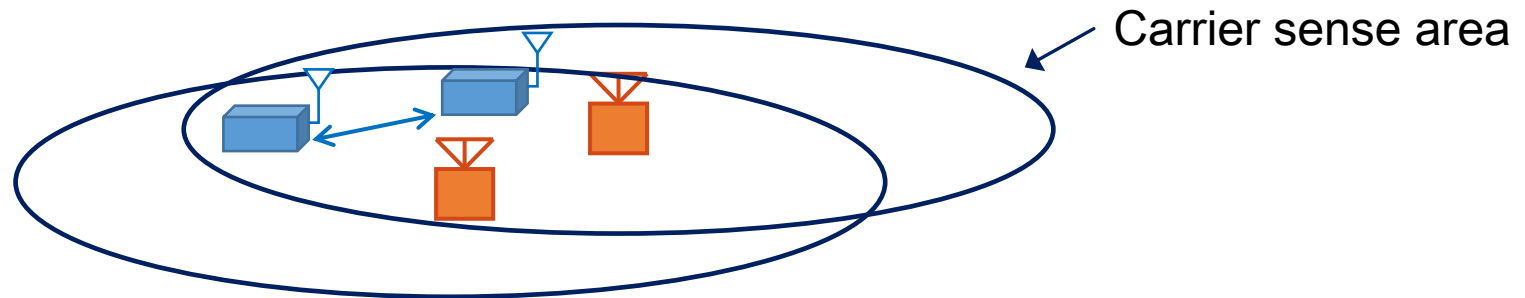


c. $P_{ai} > P$

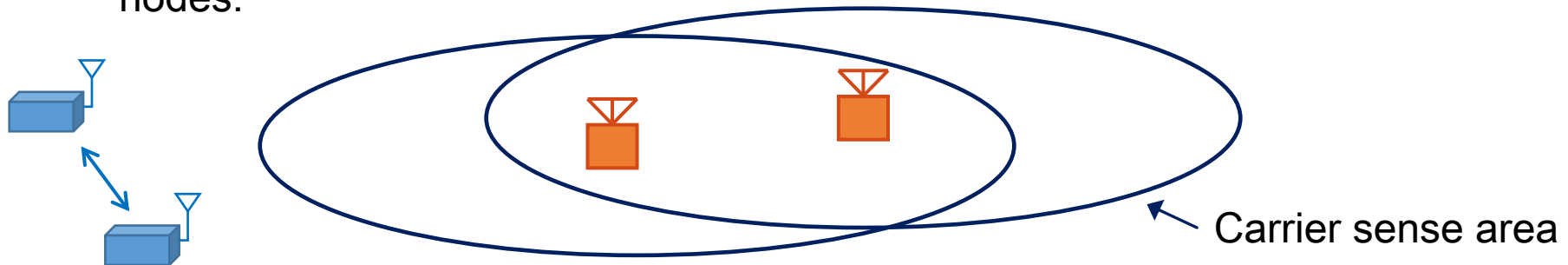
- This node is not detected by carrier sense of the sensor node.
- This node does not give interference to the sensor node.

- The spectrum manager selects the channel to avoid HNP and notifies the channel to sensor nodes.
 - Second, the spectrum manager categorize the channels that whether HNP occurs or not.
 - The spectrum manager recognizes energy relation to surrounding nodes for two sensor nodes.
 - ✓ Channel is categorized into following 3 patterns .
 1. Sensor nodes can share the channel without HNP by CSMA/CA.
 2. Sensor nodes can utilize the spatially free channel without HNP.
 3. Sensor nodes cause HNP or are caused HNP.

1. Sensor nodes can share the channel without HNP by CSMA/CA.
 - Two sensor nodes can work carrier sense to the surrounding nodes.



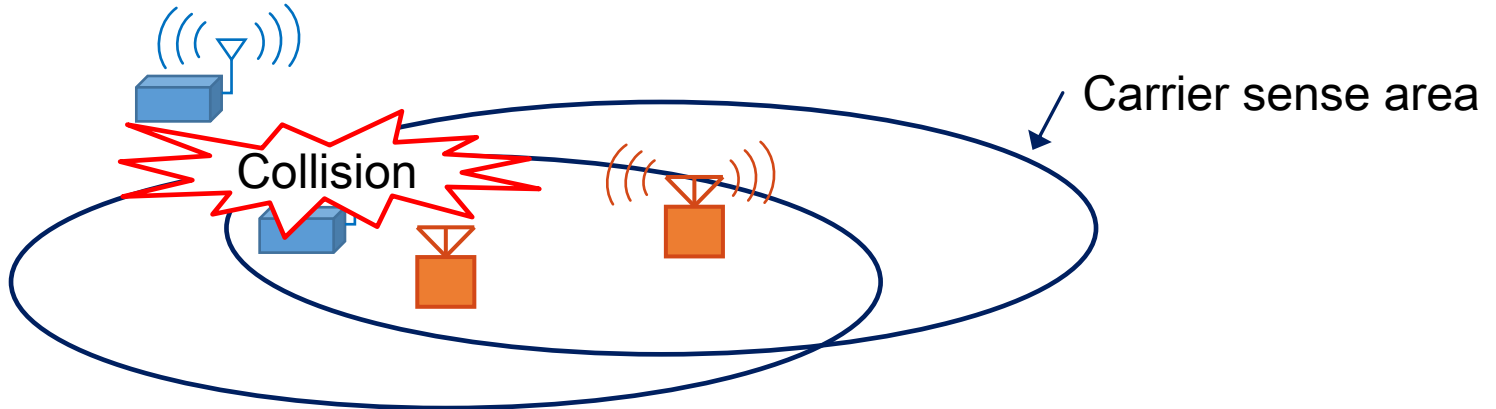
2. Sensor nodes can utilize the spatially separated channel without HNP.
 - Two sensor nodes do not interfere to surrounding nodes because two sensor nodes receive allowable interference level signal from surrounding nodes.



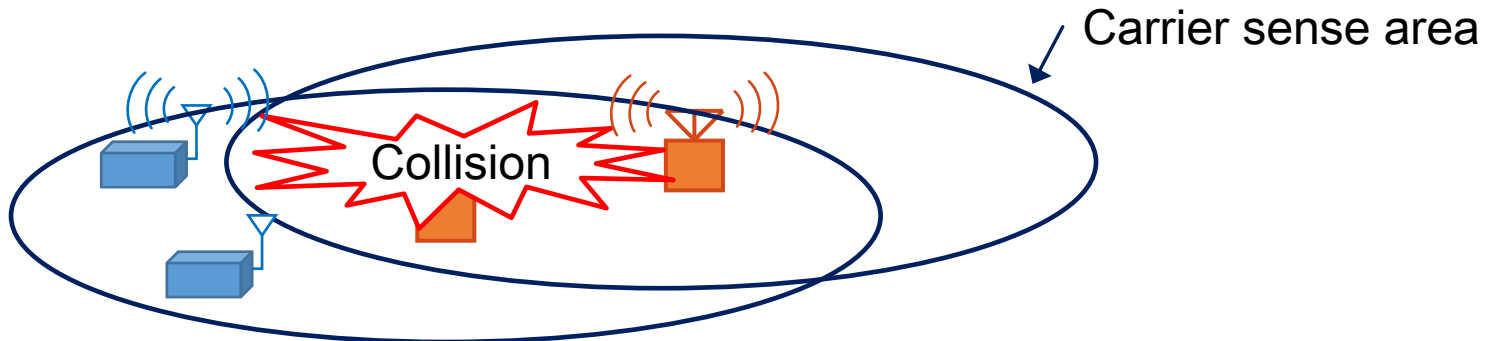
- These channels are selected by the spectrum manager.

3. Sensor nodes cause HNP or are happened HNP.

- Sensor nodes cause HNP on this channel.



- Sensor nodes are happened HNP on this channel.



- These channels are not selected by the spectrum manager.

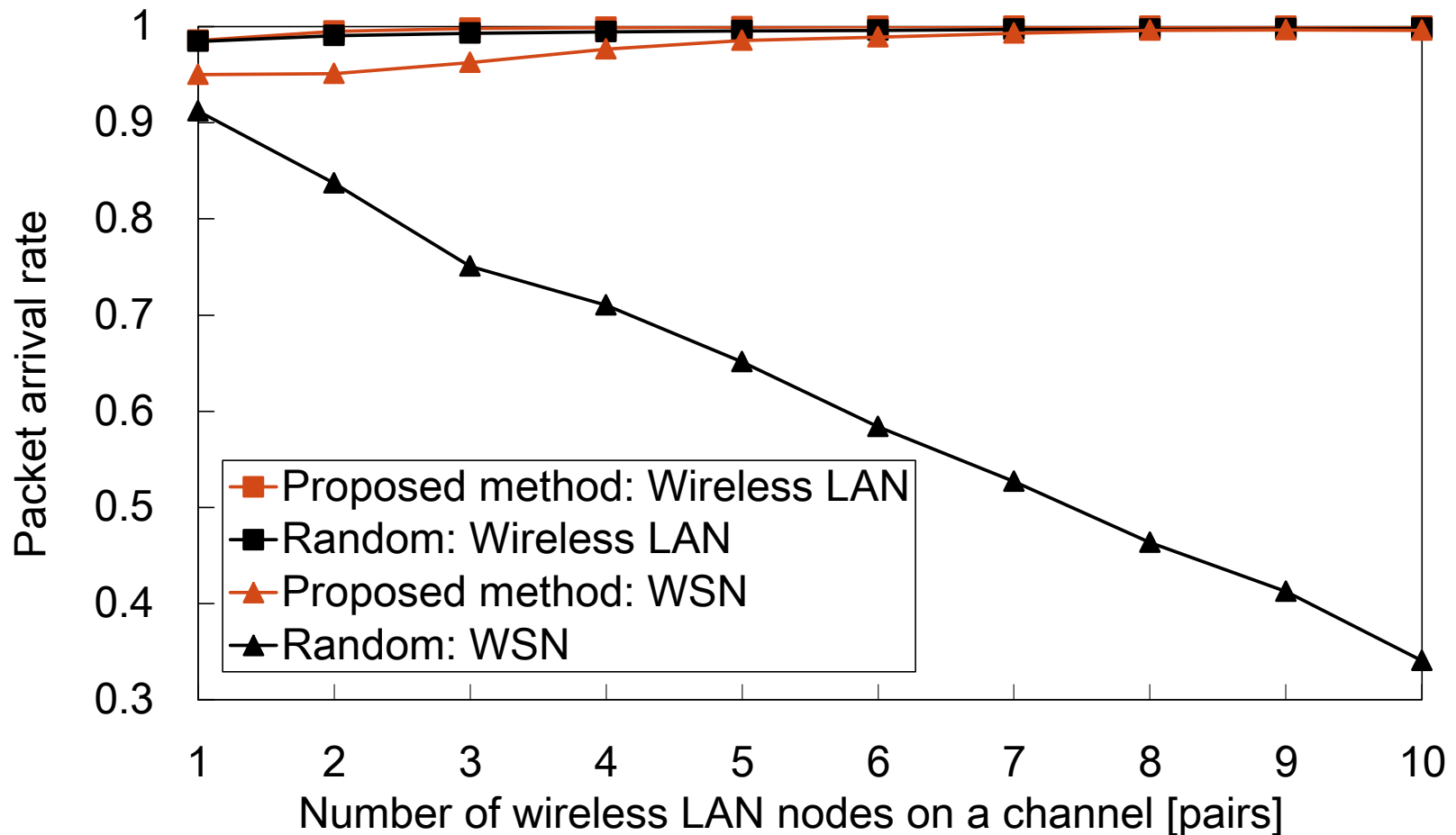
- The spectrum manager selects the channel to avoid HNP and notifies the channel to sensor nodes.
 - Third, the spectrum manager selects the channel of pattern1 or pattern2.
 - ✓ These channels is not happened HNP.
- This channel selection solves HNP, and packet loss reduced.

- Number of wireless LAN nodes increase in the area.
 - Packet arrival rate
 - Channel selection ratio
- ✓ Only interference between Wireless LAN and WSN.

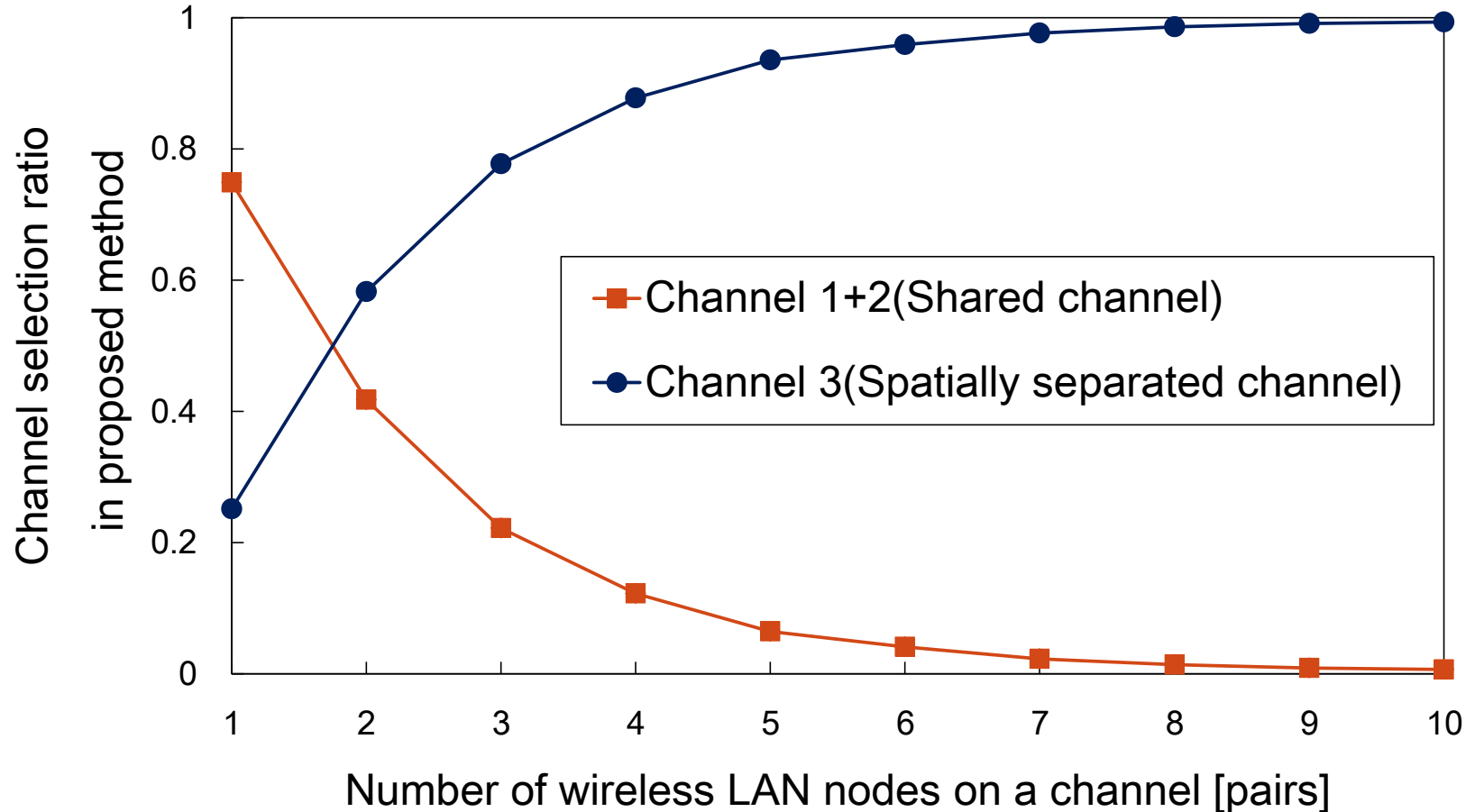
Number of wireless LAN nodes on one channel	1 – 10 [pairs]
Number of wireless sensor network nodes	2
Nodes location	Random
Average AWGN level	–100[dBm]
Transmission power	10[dBm]
Carrier sense level	–62[dBm]
Packet loss SINR	10[dB]

Area size	100×100[m ²]
Band	2.4[GHz]
Path loss factor	3.5
Number of channels	3
Channel	Path loss, AWGN
Number of trials	10000

- ✓ Channel 1, 2: Share band on Wireless LAN and WSN.
- ✓ Channel 3: Spatially separated channel.



- In random channel selection, when number of wireless LAN increases, packet arrival rate decreases.
- Proposed method can avoid interference, so packet arrival rate is maintained.



- If number of wireless LAN nodes are more than 2 pairs, HNP happens in channels.
- ✓ Select channel 3(spatially non interference channel).

■ Background

- HNP happens on channel by some radio systems.
- We must select the channel avoiding HNP.

■ Proposed method

- Phase 1: Database construction
 - ✓ Sensor nodes gather surrounding radio environment information.
 - ✓ This information is physical layer and MAC layer.
- Phase 2: Database utilization
 - ✓ By using the Database, some channels are categorized.
 - ✓ The spectrum manager uses the channel without HNP and notifies it.
- This method improved packet loss.

■ Future work

- Temporal database of construction and utilization.
- Increment of sensor nodes .