



The University of Electro-Communications



# Spectrum Shared Wireless Sensor Networks based on Radio Environment Database

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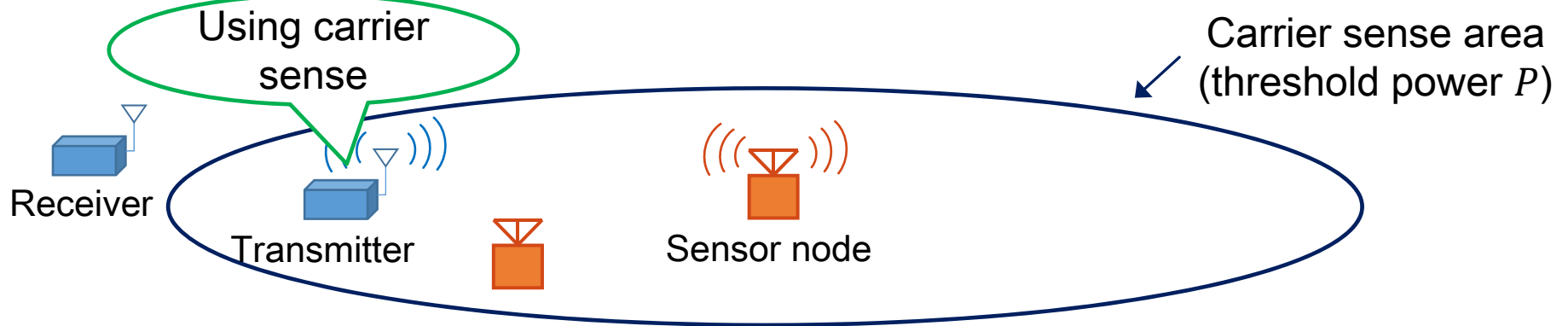
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- Current spectrum band in Wireless communications
  - License band : Licensed user only use this band.
  - Shared band : Multiple systems use the same band.
    - ✓ ISM band is unlicensed band on 2.4GHz band.
    - ✓ Multiple applications: Wireless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

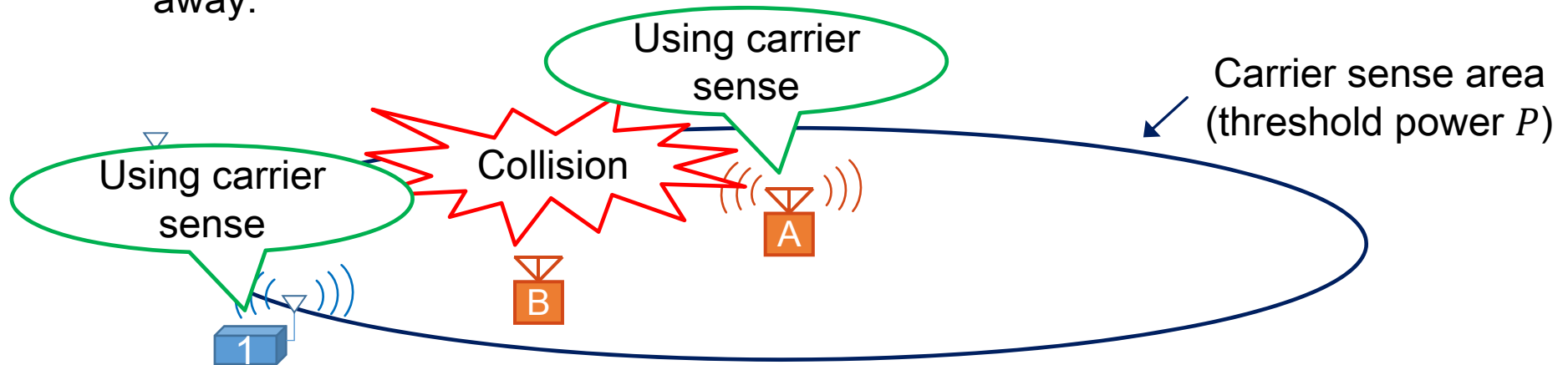
## ■ CSMA/CA

- 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.



- We want to communicate comfortably, but 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

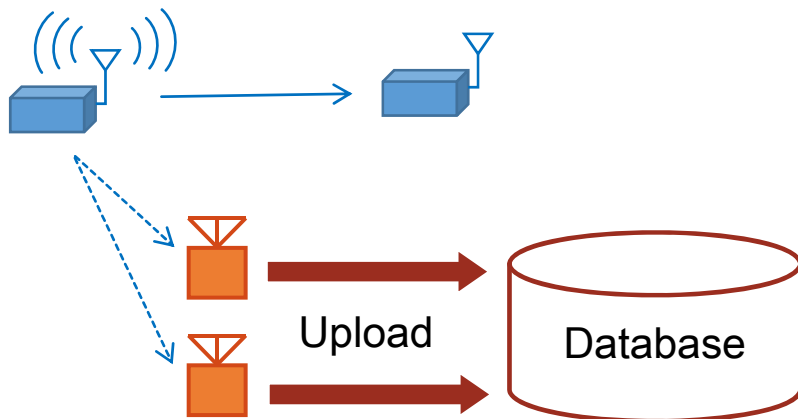
### ● Purpose :

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

## ■ Proposed method consists of two phases.

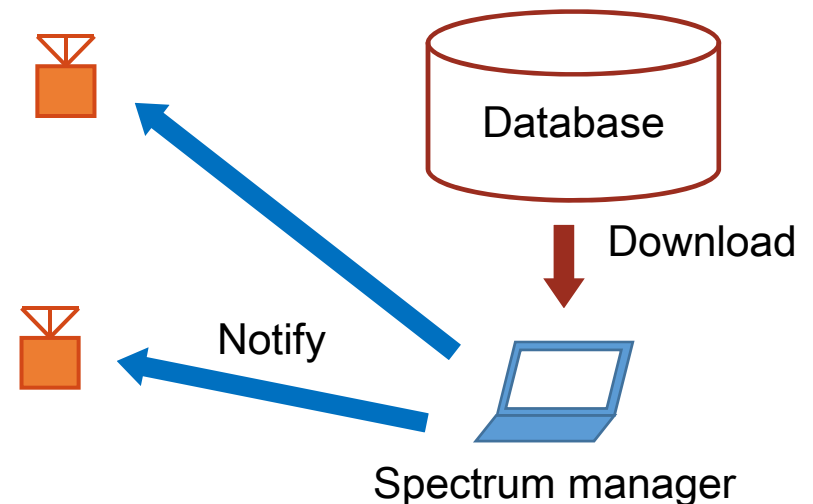
### ● Phase 1: Database construction.

- ✓ 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.

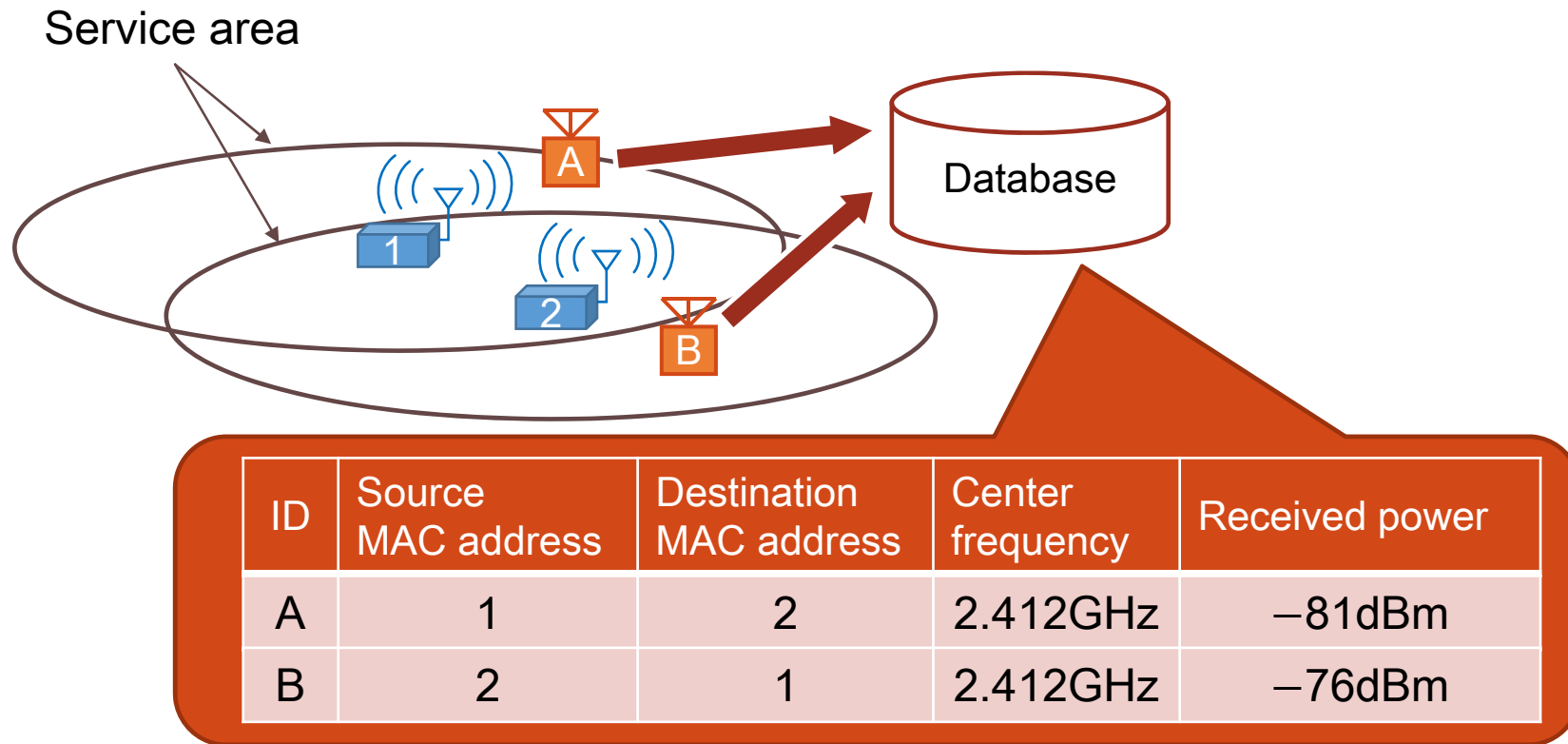


- Sensor nodes gather surrounding radio information and upload it to the Database.
  - Each sensor node gathers surrounding radio information.
    - ✓ These sensor nodes use software radio.
    - ✓ Gathered information is Physical layer information(received power, frequency) and MAC layer information(destination/source MAC address)
  - Sensor nodes upload gathered information.
    - ✓ The database stores several information.
      1. Sensor node ID of itself.
      2. Source MAC address of observation signal.
      3. Destination MAC address of observation signal.
      4. Center frequency of observation signal.
      5. Instantaneous received power of observation signal.

## Phase 1: Database construction

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- In order to utilize data for all nodes, this information is needed to be converted to statistical data.
- The surrounding radio environment of sensor nodes is shown.

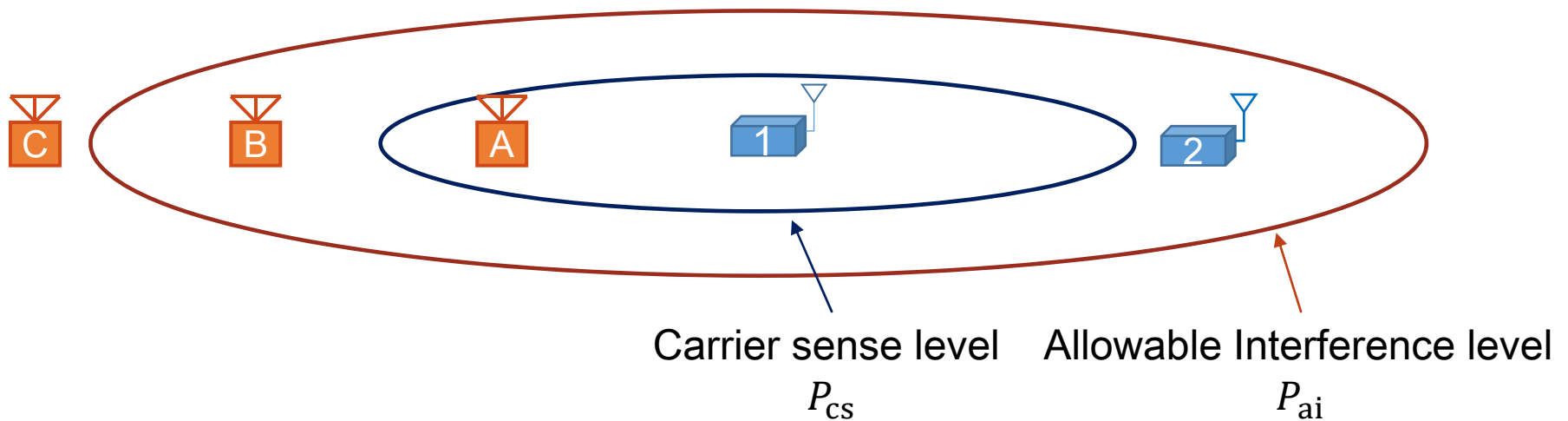


The surrounding node's information is stored in the Database!

## Phase 2: Database utilization

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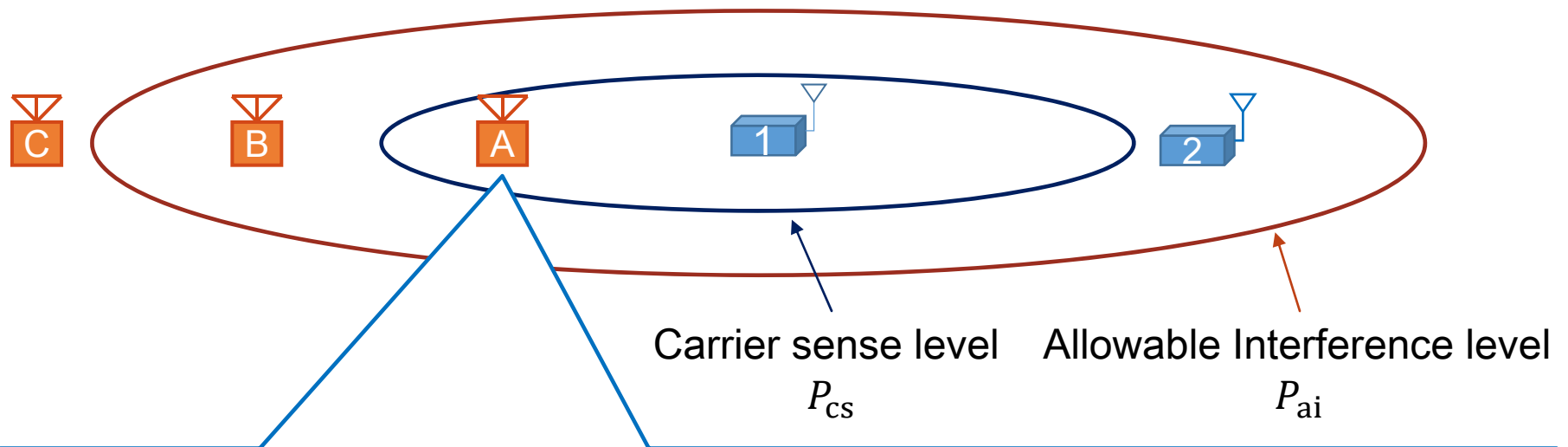
- The spectrum manager selects the channel to avoid HNP and notifies the channel to sensor nodes.
- The spectrum manager categorizes surrounding nodes of sensor nodes based on average received power  $P$  in the database.



ID	Source MAC address	Destination MAC address	Center frequency	Received power
?	1	2	2.412GHz	$P$



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



A)  $P > P_{cs}(-62\text{dBm})$

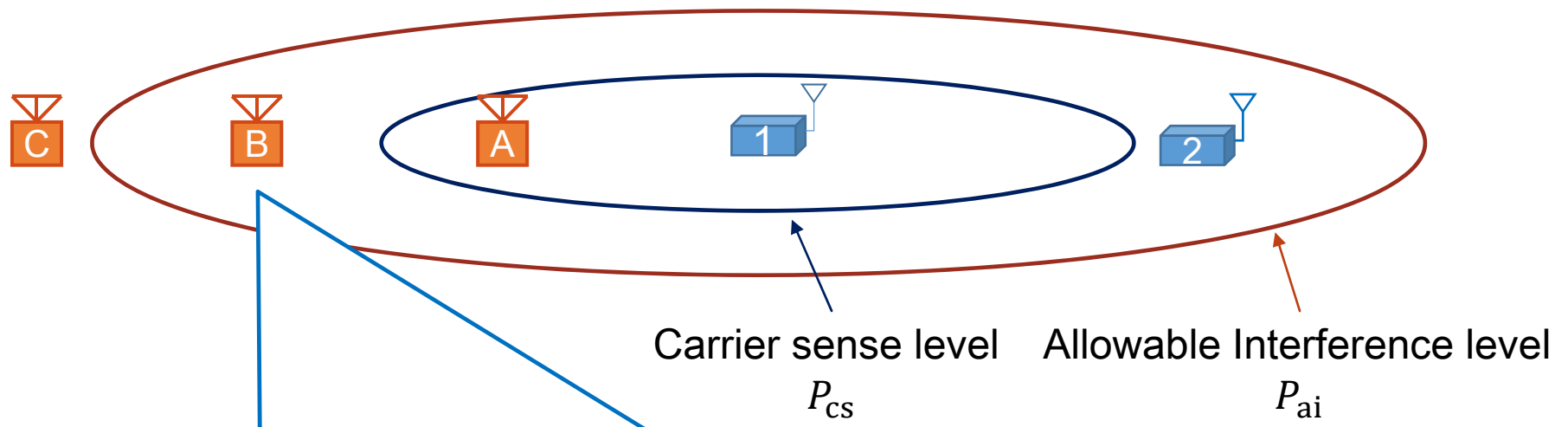
- The node A can detect the node 1 by carrier sense .

ID	Source MAC address	Destination MAC address	Center frequency	Received power
A	1	2	2.412GHz	-55

## Phase 2: Database utilization

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

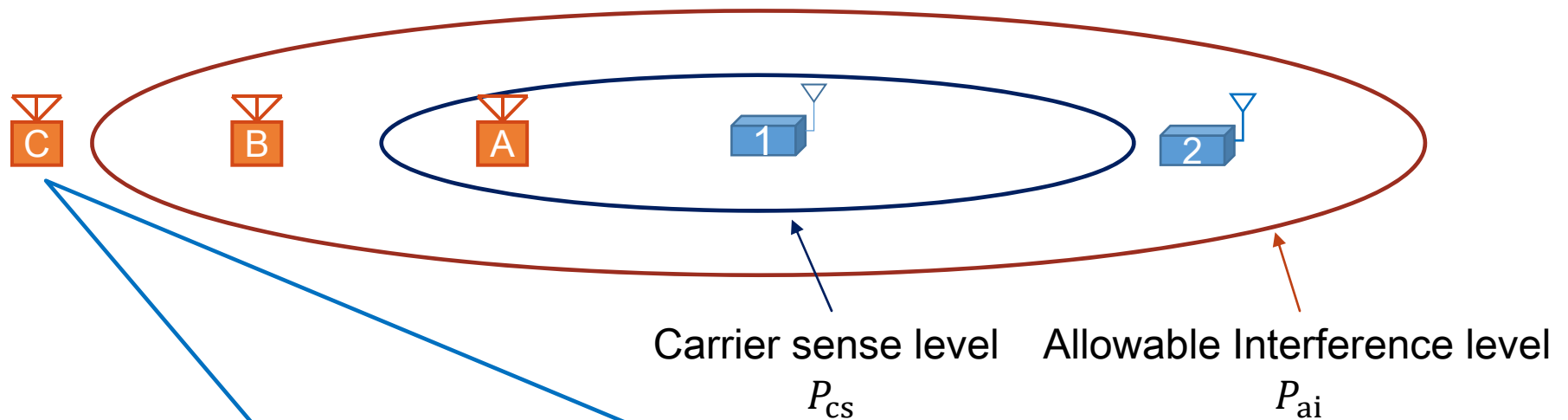


B)  $P_{cs}(-62\text{dBm}) > P > P_{ai}(-85\text{dBm})$

- The node B cannot detect the node 1 by carrier sense.
- The node B gives interference to the node 1.

ID	Source MAC address	Destination MAC address	Center frequency	Received power
B	1	2	2.412GHz	-75

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



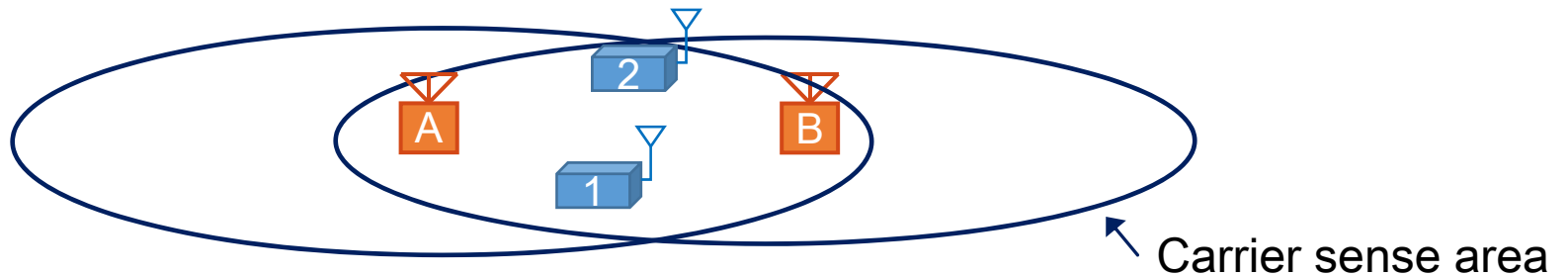
C)  $P_{ai}(-85\text{dBm}) > P$

- The node C cannot detect the node 1 by carrier sense.
- The node C does not give interference to the node 1.

ID	Source MAC address	Destination MAC address	Center frequency	Received power
C	1	2	2.412GHz	-90

- The spectrum manager selects the channel to avoid HNP and notifies the channel to sensor nodes.
  - The spectrum manager categorizes the channels that whether HNP occurs or not.
  - The spectrum manager recognizes energy relation to surrounding nodes of destination sensor node and source sensor node.
  - ✓ 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 separated channel without HNP.
    3. Sensor nodes cause HNP or are caused HNP.

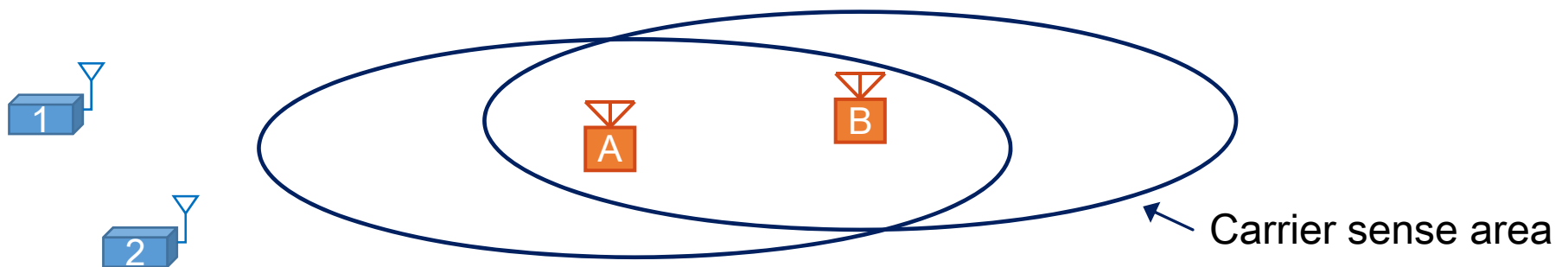
1. Sensor nodes can share the channel without HNP by CSMA/CA.
  - Two sensor nodes can work carrier sense to the surrounding nodes.



ID	Source MAC address	Destination MAC address	Center frequency	Received power
A	1	2	2.412GHz	-55dBm
A	2	1	2.412GHz	-60dBm
B	1	2	2.412GHz	-50dBm
B	2	1	2.412GHz	-60dBm

- This channel is selected by the spectrum manager.

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

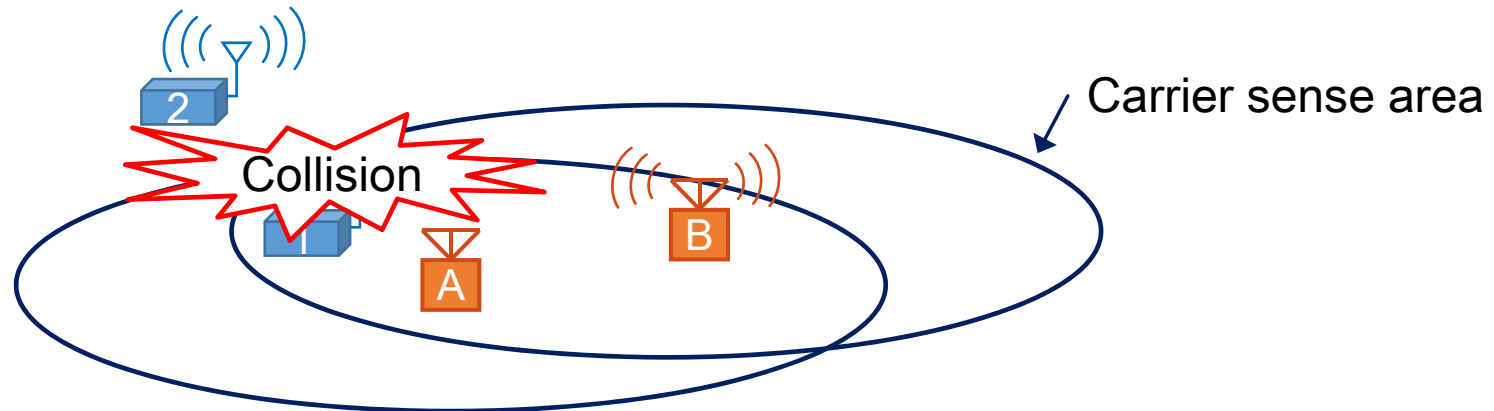


ID	Source MAC address	Destination MAC address	Center frequency	Received power
A	1	2	2.412GHz	-85dBm
A	2	1	2.412GHz	-90dBm
B	1	2	2.412GHz	-95dBm
B	2	1	2.412GHz	-95dBm

- This channel is selected by the spectrum manager.

### 3. Sensor nodes cause HNP or HNP is caused.

- Sensor nodes cause HNP on the channel.

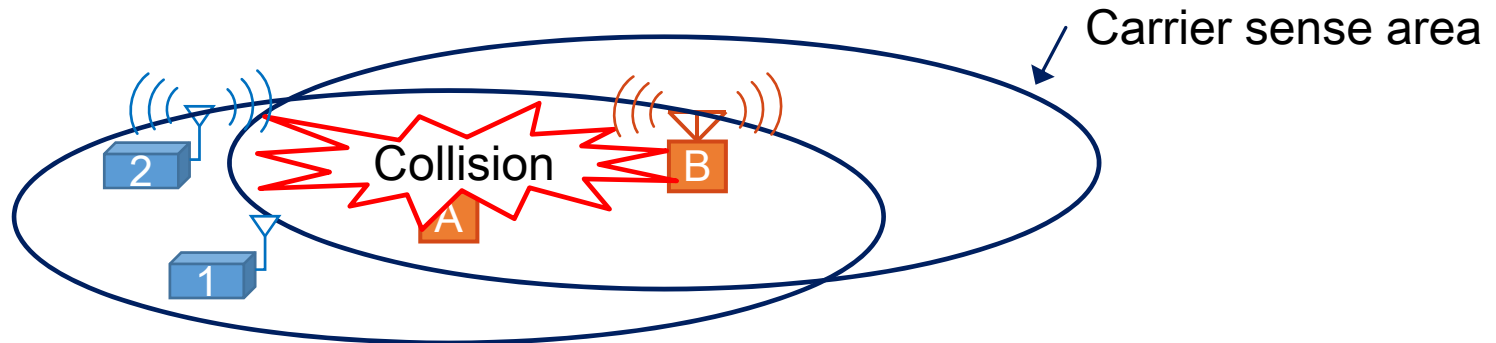


ID	Source MAC address	Destination MAC address	Center frequency	Received power
A	1	2	2.412GHz	-55dBm
A	2	1	2.412GHz	-75dBm
B	1	2	2.412GHz	-60dBm
B	2	1	2.412GHz	-80dBm

- This channel is not selected by the spectrum manager.

### 3. Sensor nodes cause HNP or HNP is caused.

- HNP is caused on the channel.

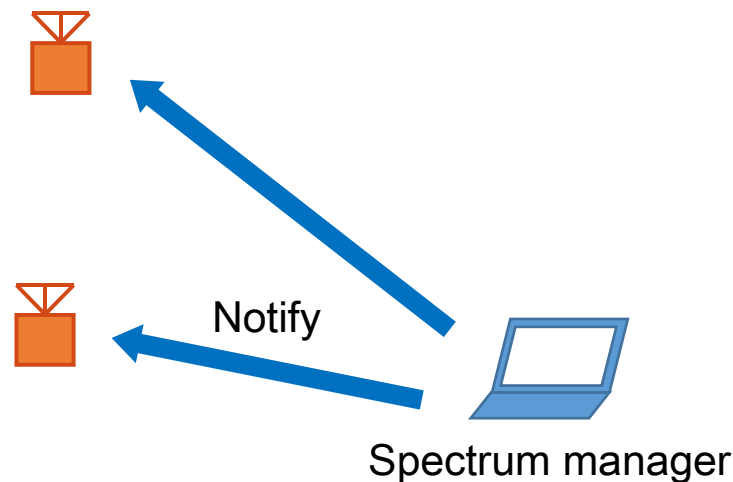


ID	Source MAC address	Destination MAC address	Center frequency	Received power
A	1	2	2.412GHz	-55dBm
A	2	1	2.412GHz	-60dBm
B	1	2	2.412GHz	-70dBm
B	2	1	2.412GHz	-75dBm

- This channel is not selected by the spectrum manager.



- The spectrum manager selects the channel to avoid HNP and notifies the channel to sensor nodes.
  - The spectrum manager selects the channel of pattern1 or pattern2.
    - ✓ These channels are which HNP is not caused.
  - The spectrum manager notifies the channel to the sensor nodes, and the sensor nodes use the channel.

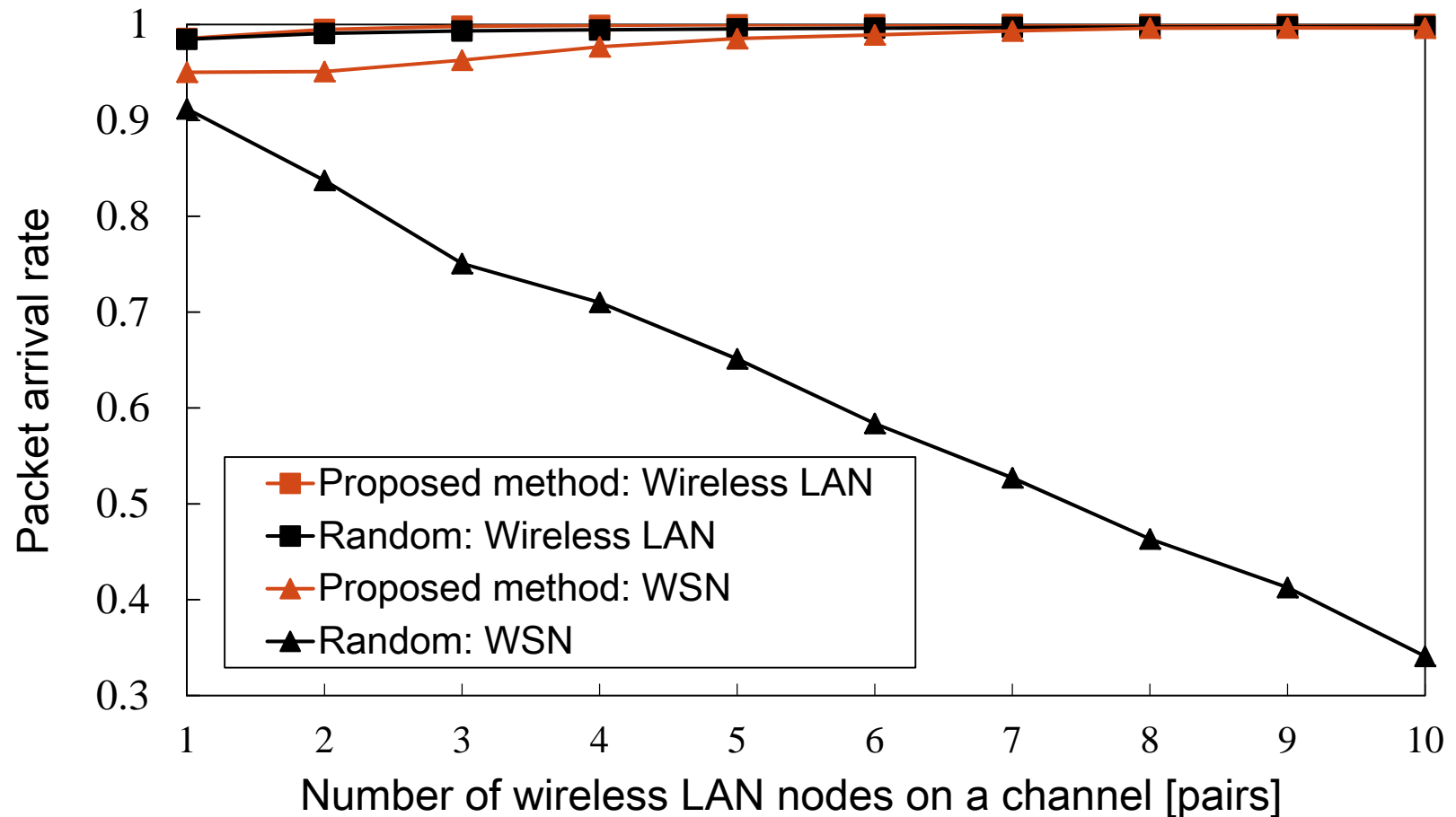


- This channel selection method can solve HNP, and packet loss will reduce.

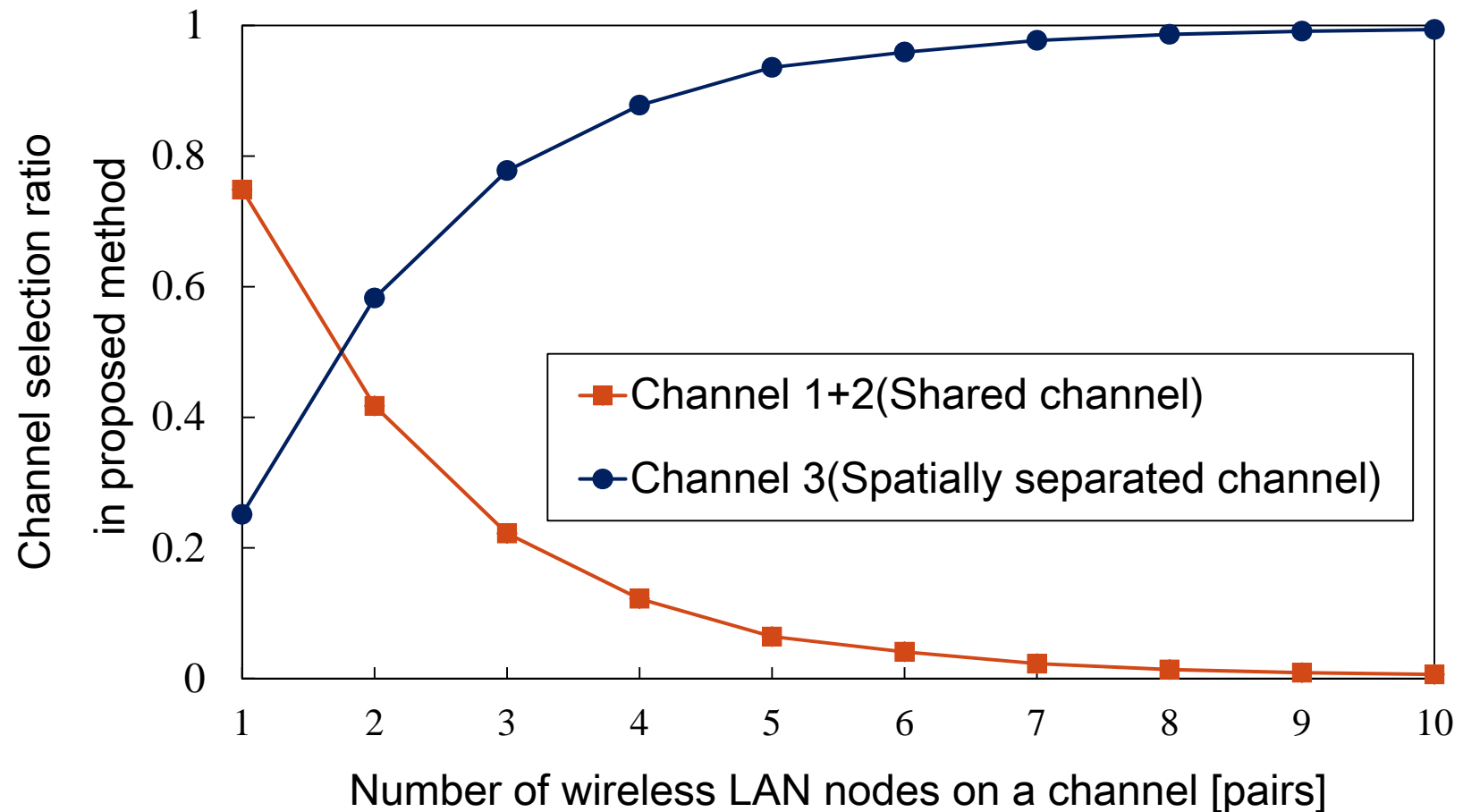
- Number of wireless LAN nodes increase in the area.
  - Packet arrival rate
  - Channel selection ratio
  - ✓ Only interference between Wireless LAN and WSN.

Number of wireless LAN nodes on one channel	1 – 10 [pairs]	Area size	100×100[m <sup>2</sup> ]
Number of wireless sensor network nodes	2	Band	2.4[GHz]
Nodes location	Random	Path loss factor	3.5
Average AWGN level	–100[dBm]	Number of channels	3
Transmission power	10[dBm]	Channel	Path loss, AWGN
Carrier sense level	–62[dBm]	Number of trials	10000
Packet loss SINR	10[dB]		

- ✓ 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 avoids interference, so packet arrival rate can be maintained.



- When number of wireless LAN nodes is more than 2 pairs, HNP happens on channels.
  - ✓ Therefore, proposed method selects the channel 3 which is spatially separated.

## ■ 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



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Thank you for attention.