# Field Tests of Database-assisted V2V Communications over TV White Space

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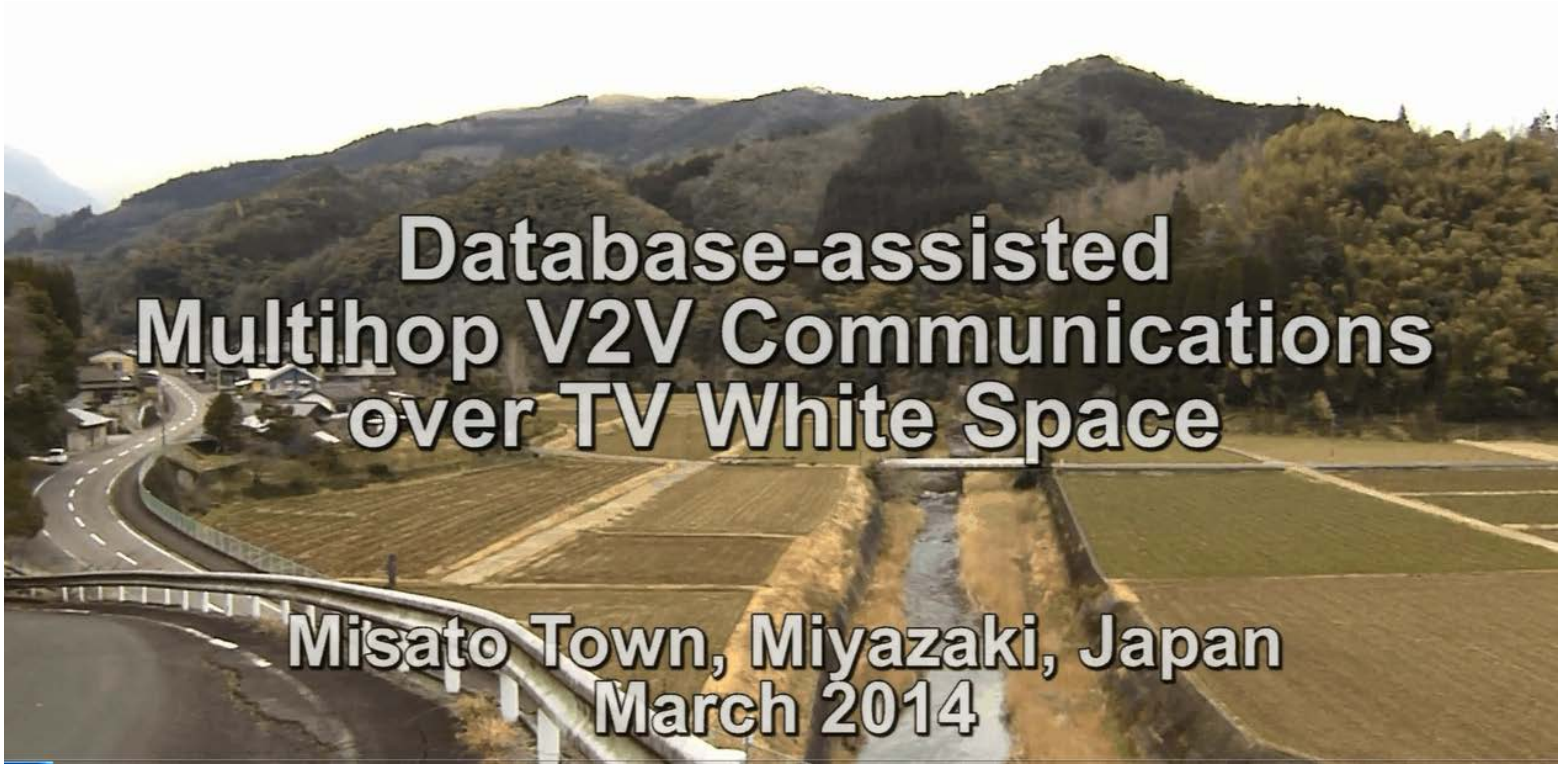
# In a nutshell



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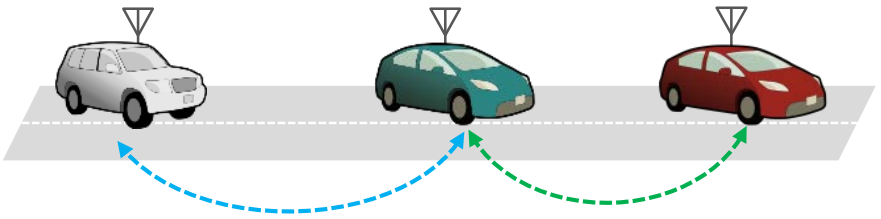


# Motivation – Why V2V Communications over White Space?

- Advanced driving support applications
  - rely on wireless communications among the vehicles
  - increase driver awareness and situation perception
  - Improve traffic flow efficiency

- Spectrum to be used by Intelligent Transportation Systems (ITS)
  - US: 75 MHz of spectrum in 5.9 GHz band for dedicated short-range communications (DSRC)
  - Europe: 30 MHz of spectrum in the 5.8 GHz band
  - Japan: 9 MHz of spectrum centered at 760 MHz band

- Standards supporting vehicular communications have been designed
  - ARIB STD-T109 in Japan
  - IEEE 1609 and IEEE 802.11p elsewhere

# Motivation – Why V2V Communications over White Space?

- Not only communications among vehicles, but also among vehicles, objects and people expected to become ubiquitous
  - Significant increase in spectrum and capacity requirements
- One recent study* looks into the spectrum requirements of vehicular communications for safety applications
  - More than 80 MHz of spectrum is deemed as necessary for a packet error ratio of 1%.
- Offload time-insensitive applications from the licensed band
- May further be enhanced by the developments in automated driving systems
  - Exchange significant amount of sensor and image data in real-time


*L. Shi and K. W. Sung, "Spectrum Requirement for Vehicle-to-Vehicle Communication for Traffic Safety," in *IEEE Vehicular Technology Conference 2014 Spring*, Seoul, S. Korea, May 2014.

# Dynamic Spectrum Access for V2V Communications

- Potential solution: look for spatially and/or temporally unused spectrum in the TV band because of
  - Relatively static channel utilization by incumbents
  - Favorable propagation conditions
- Problem: Mobility and dynamic spectrum access don’t match well
- Existing TV White Space architectures assume
  - No mobility, or very low mobility
  - Centralized rather than ad-hoc architecture

# Spectrum awareness in the vehicular environment

- Existing approaches are
  - Spectrum sensing
  - Geolocation database querying
- Our solution is to use both approaches
  - Database approach is prioritized over sensing
- Toward implementing database access for highly mobile ad-hoc networks we face some unique challenges
  - How to obtain and exchange of information about spectrum usage?
  - How to establish the network depending on the location, speed and direction of nodes?
  - How to establish routing and maintain connectivity even when channel availability changes?

# Design outline

1. Exchange **localization** information using DSRC beacons

vehicle ID, location, speed, heading and acceleration

2. Form **swarms** of vehicles and establish spectrum information **distribution areas**

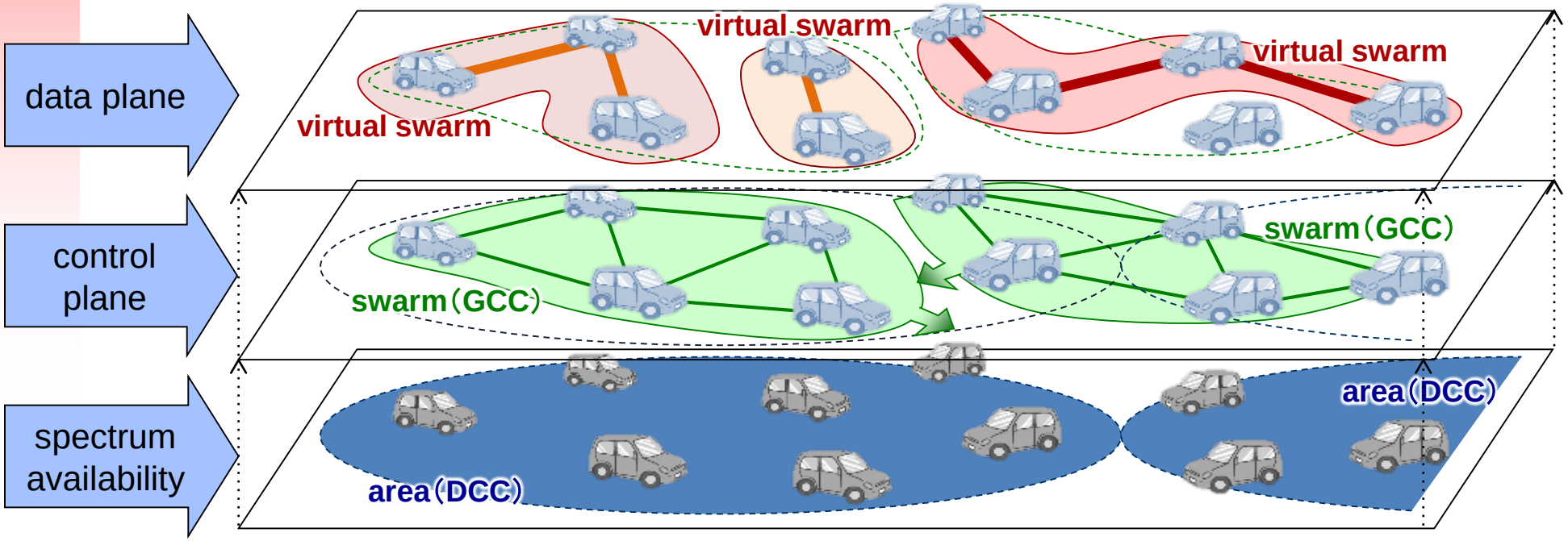
3. Select a **proxy** to obtain and distribute database information

Tasks for the proxy:

- Access the database for all cars in the swarm
- Select the longest available channel for distribution of channel availability
- Broadcast spectrum availability over the distribution channel
- Calculate future locations and use feature approved by the FCC to download spectrum availability “in advance”

# General concept and architecture

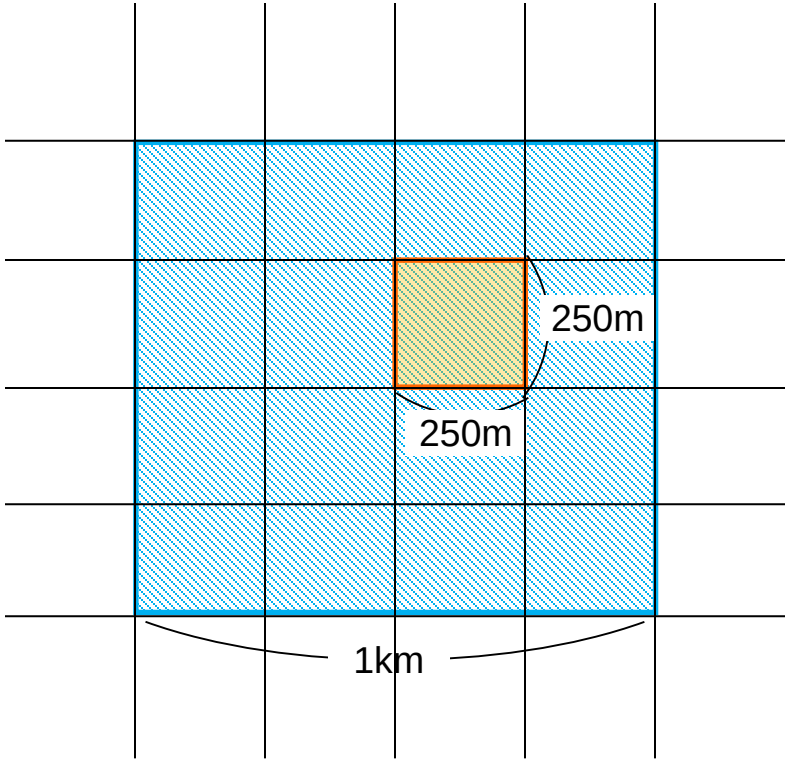
- Distribution Control Channel (DCC) is used for distribution of information on spectrum occupancy
- Group Control Channel (GCC) is used to maintain communications
  - Exchange of routing information, resource allocation, handshaking,…



# Geolocation based sharing of channel availability

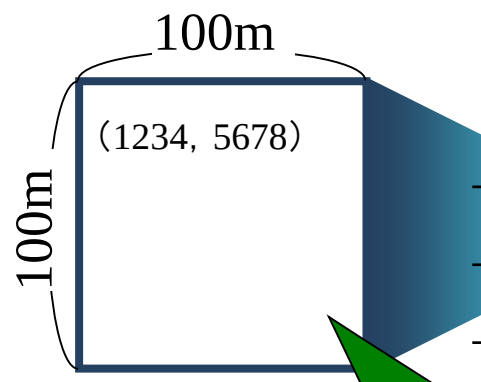
Area map is divided into square grid

A vehicle which is the closest to the middle of the database proxy access area is selected to act as a proxy



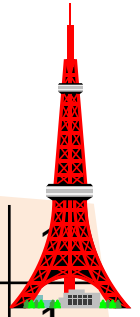

DCC area is made sufficiently large to avoid frequent channel switching

# Example Database Structure

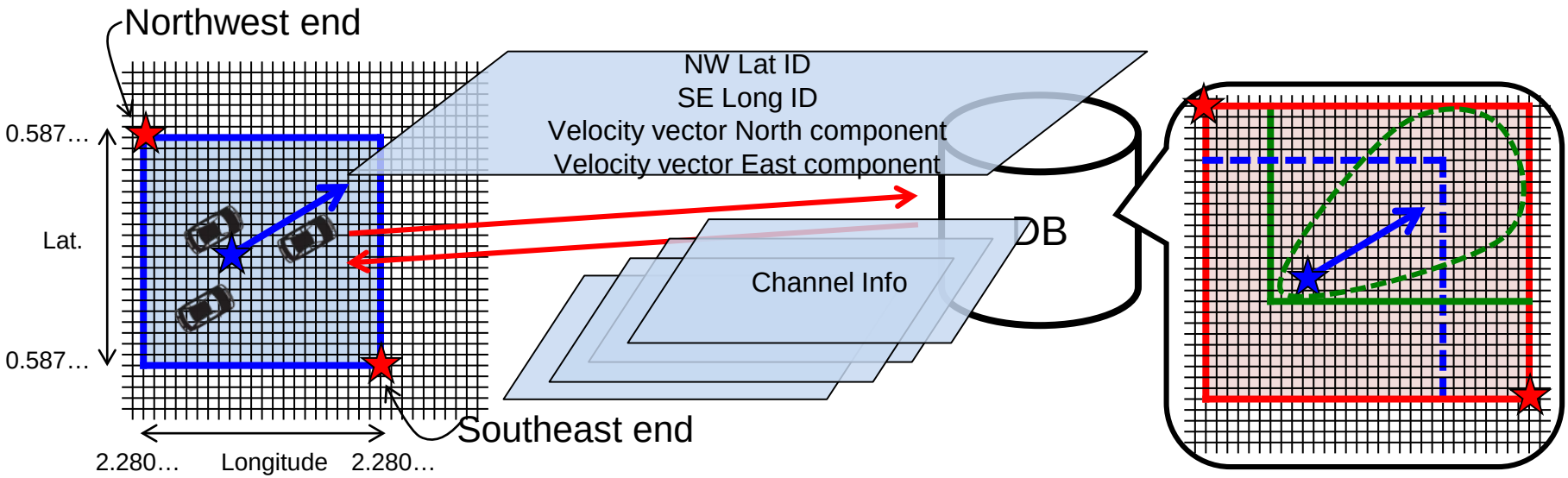



| Lat ID | Long ID | Channel ID | Status |
|---|---|---|---|
| 1234 | 5678 | 1 | 0 |
| 1234 | 5678 | 2 | 0 |
| 1234 | 5678 | 3 | 1 |
| | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 |
| | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |



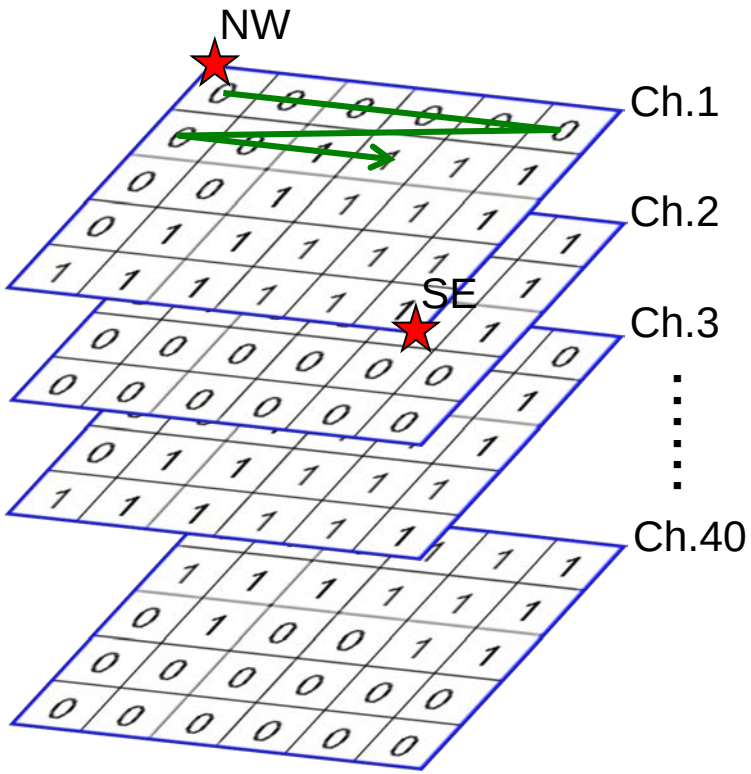
# Information Retrieval from Database



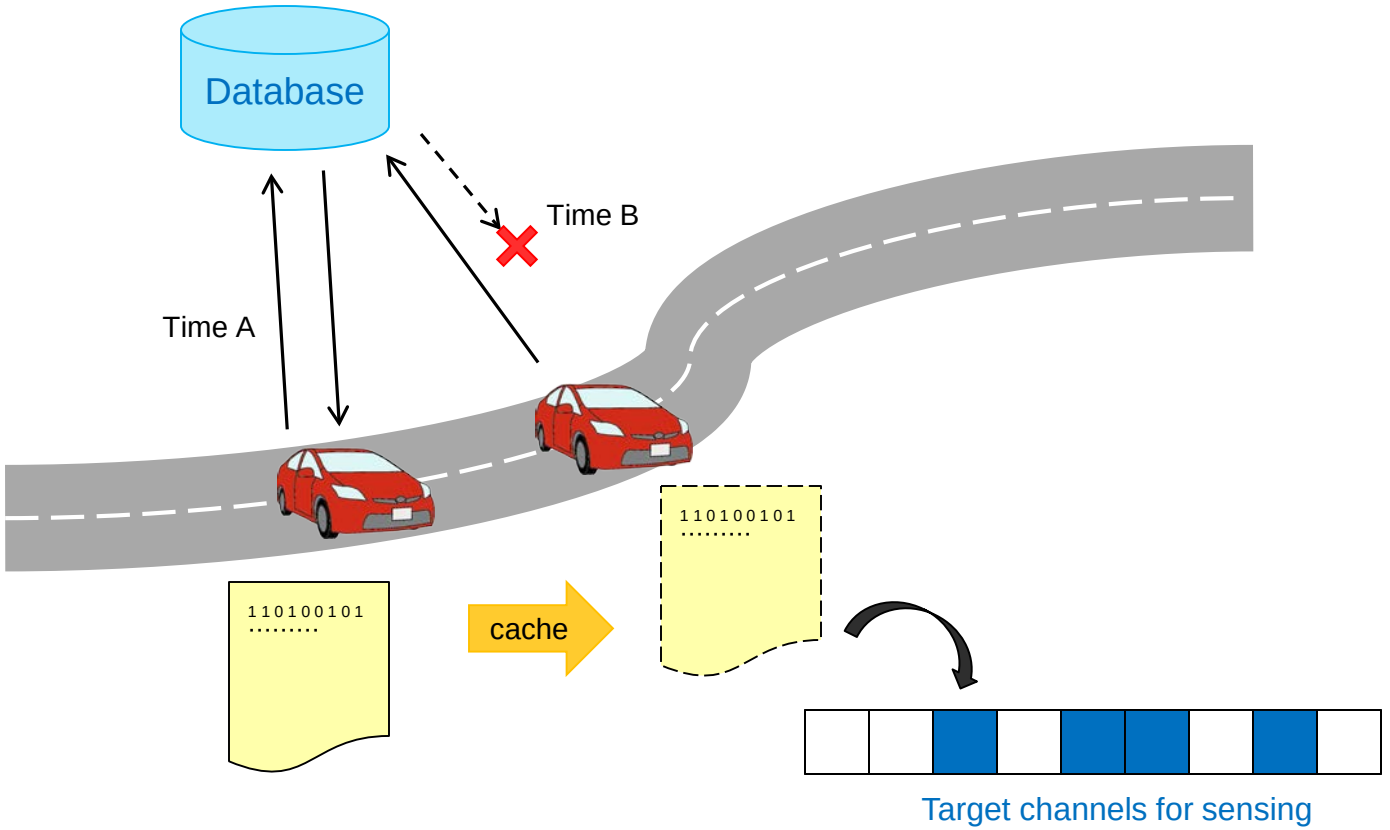
# Data Format

| NW Lat ID (Integer) | NW Long ID (Integer) |
|---|---|
| SE Lat ID (Integer) | SE Long ID (Integer) |
| 000011111111……<br>Ch.1 Status | |
| 111111111100……<br>Ch.2 Status | |
| | |

⋮

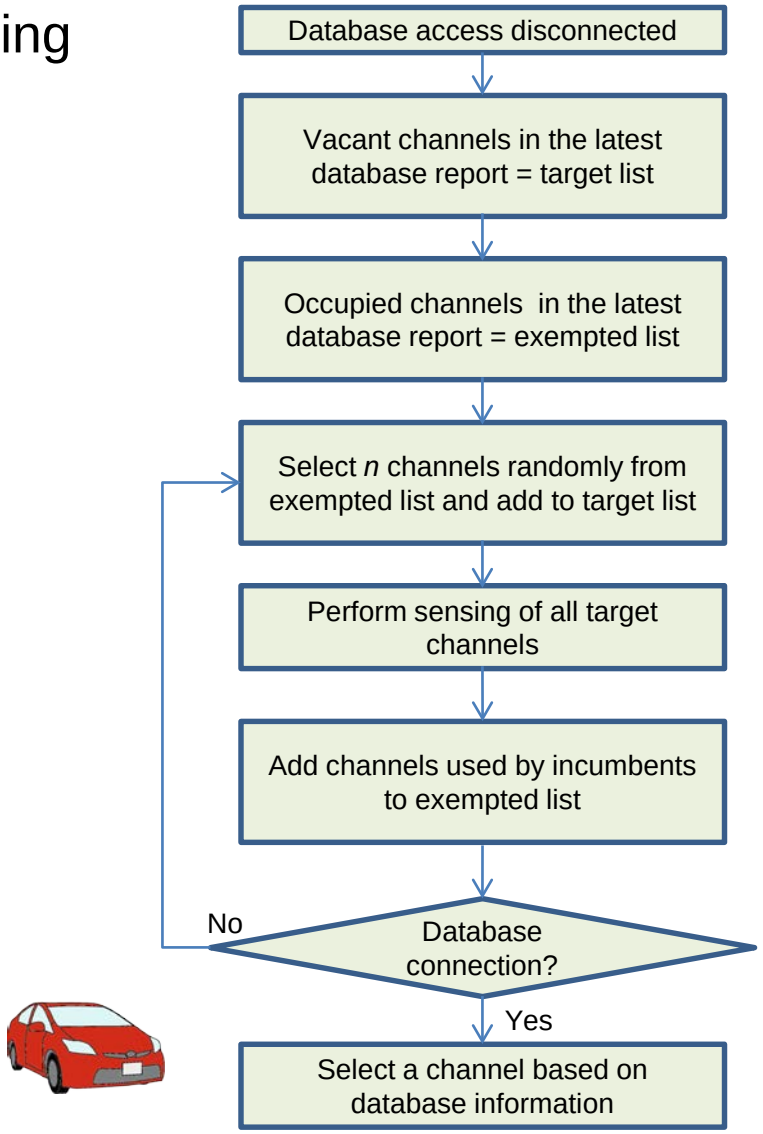


# Architecture and System Overview

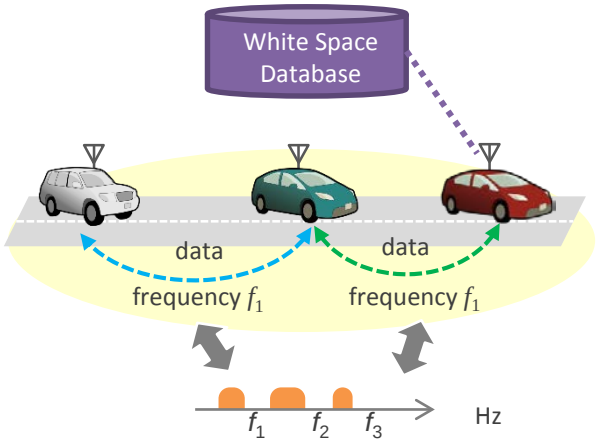


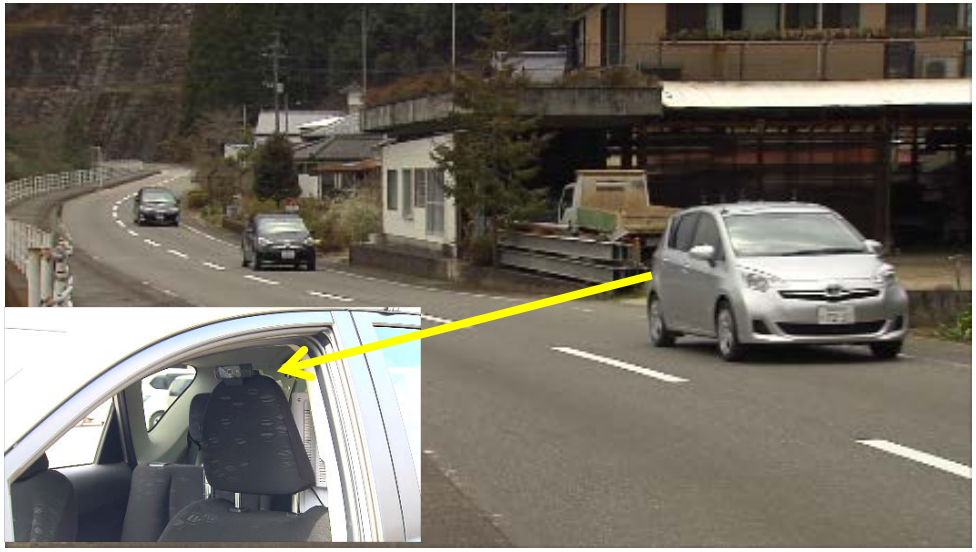
# Database and Sensing Flip-over

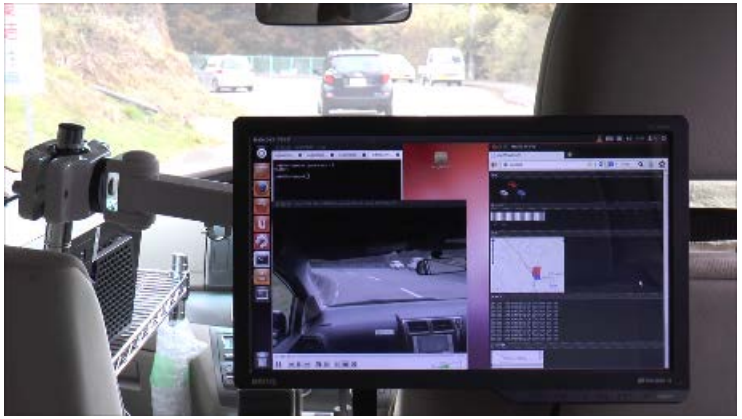
- Spectrum Starvation Hedging



# Field Tests

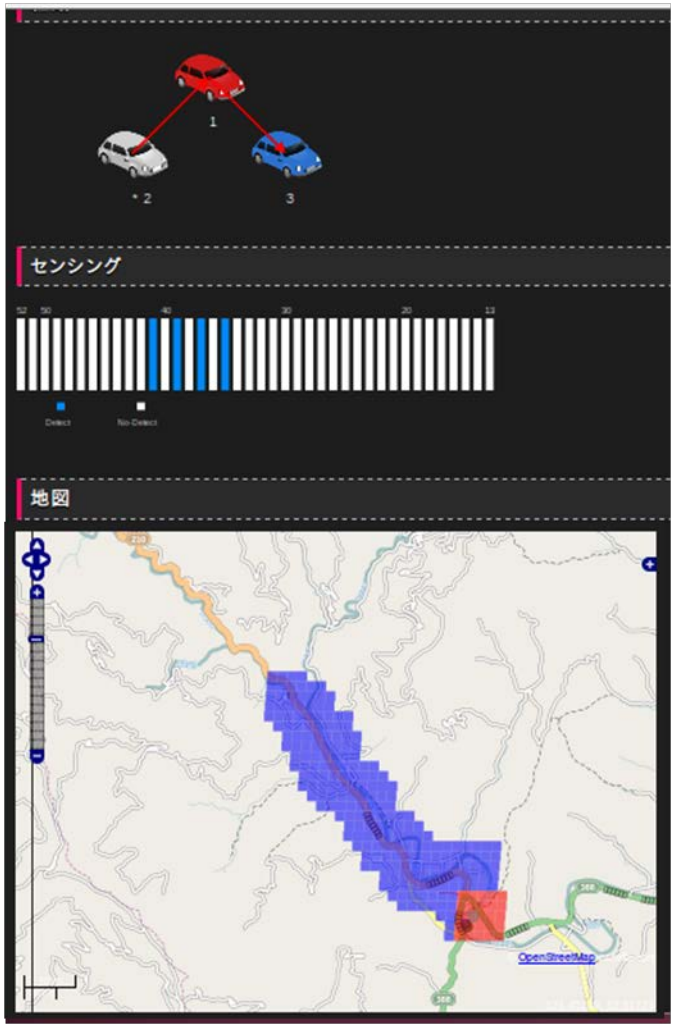




# Field Tests

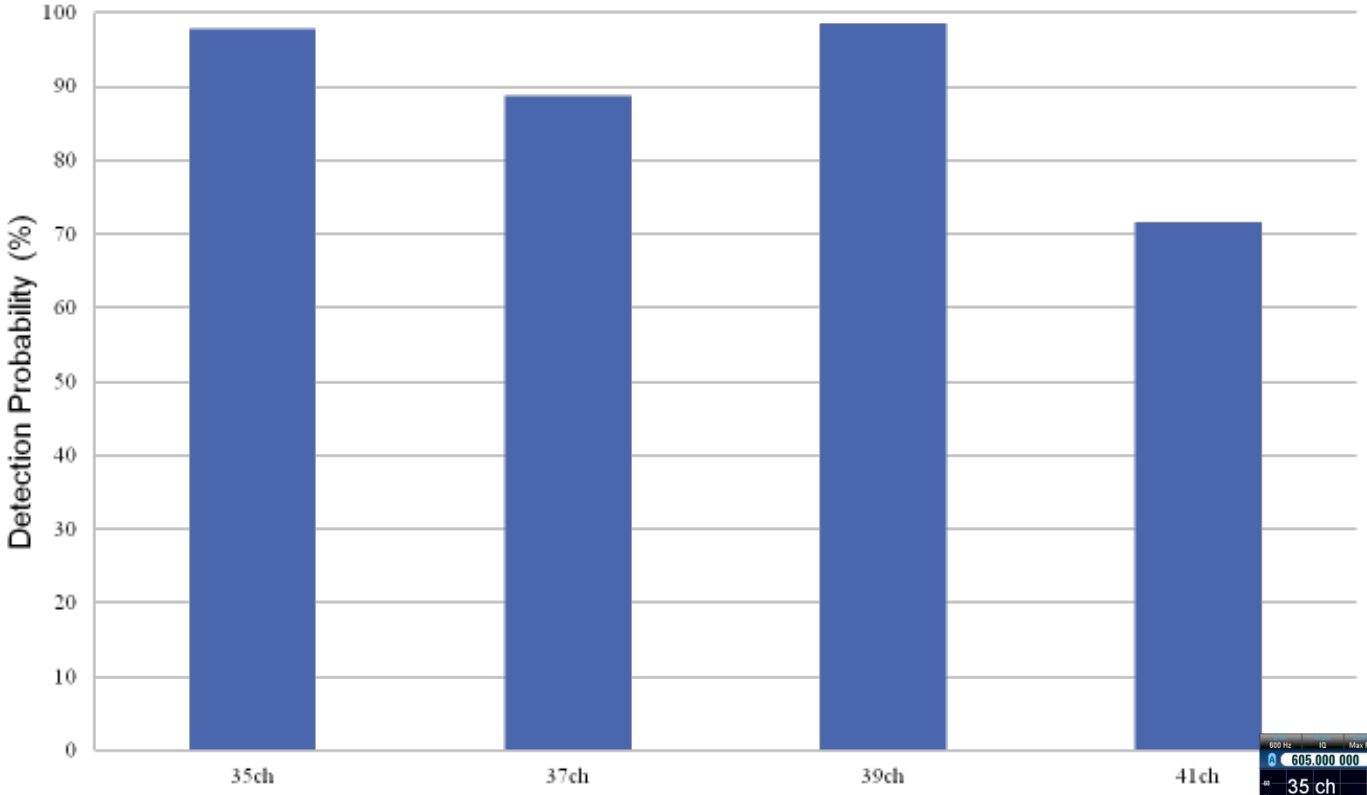
- Routing, sensing and database overlay in the rear car

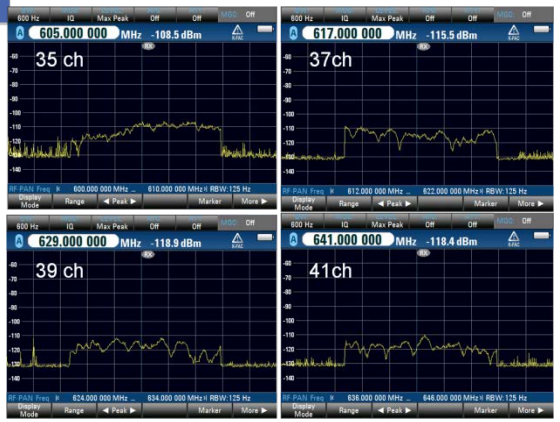


# Field Test Results

| | Throughput (TCP) | Throughput (UDP) | Packet Loss (UDP) | e2e delay |
|---|---|---|---|---|
| One hop | 4.64 Mbps | 6 Mbps | - | 3.1 msec |
| Two hops | 2.24 Mbps | 2.7 Mbps | 1% | 7.2 msec |

# Field Test Results (Incumbent Detection)

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