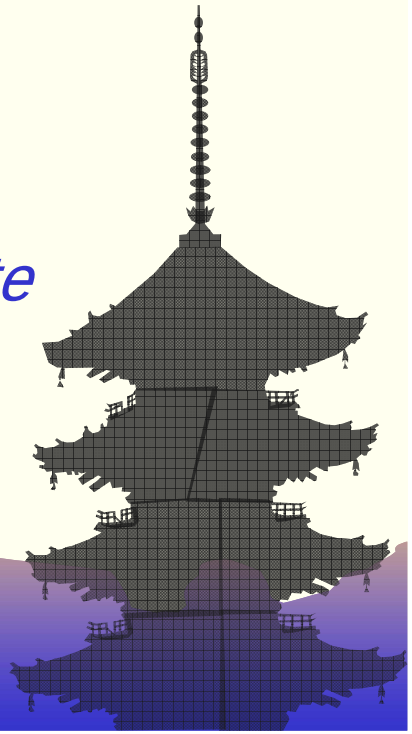
Fast-response Inter-vehicle Communications

～Supporting safe driving by the exchange of information on vehicle location and status～

Sadao Obana

Advanced Telecommunication Research Institute International (ATR), Japan



Back ground
Automobiles change our lives

Invention of gasoline automobile
Carl Benz 1886

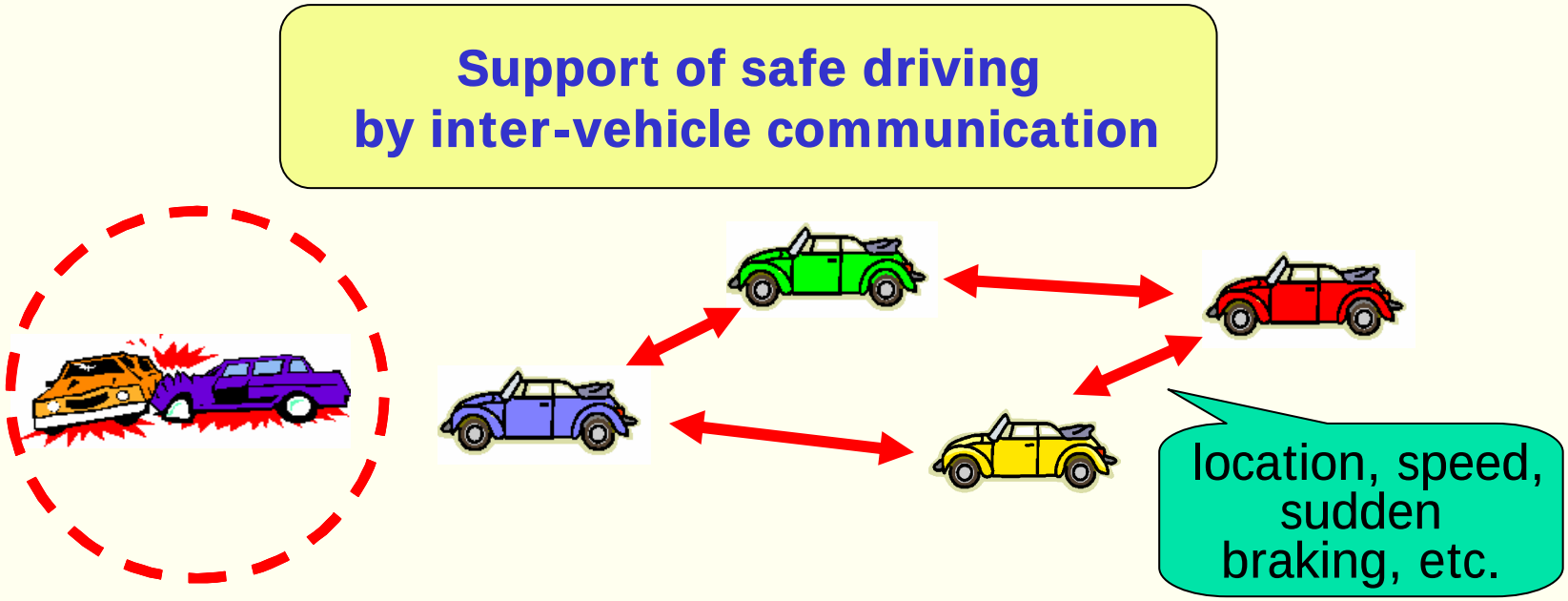
Much convenience
in our daily lives

Number of automobiles (2005) :
896 million in the world
78 million in Japan

Serious problems remain unsolved:
- **Deaths, due to traffic accidents**
  (more than 5,000 per year in Japan)
- **Loss of time, due to traffic congestion**
- **Environmental pollution, due to CO_2 emission**

This presentation introduces ;

Our R&D on a novel inter-vehicle communication technologies for safe driving, using wireless ad-hoc network, that promptly and reliably exchanges information such as on the vehicle location, speed, sudden braking, etc



Standardization on Inter-vehicle communication

IEEE 802.11p

Features: CSMA based

Frequency 5.9GHz band (10MHz × 7 ch)

US and Europe are planning to adopt IEEE802.11p.

No requirements for safe driving is defined in concrete

Japan (ITS-Forum RC-005/RC-006)

Features: CSMA based

Frequency (RC-005) 5.8GHz band (4.096 MHz ×14 ch)

(RC-006) 700MHz band (10 MHz ×1 ch)

Requirements for safe driving is defined in concrete by ASV

Overview of our R&D

- **For safe driving**

  Vehicles exchanges their information promptly and reliably. Especially, the end-to-end packet transmission delay must be as small as around one msec.

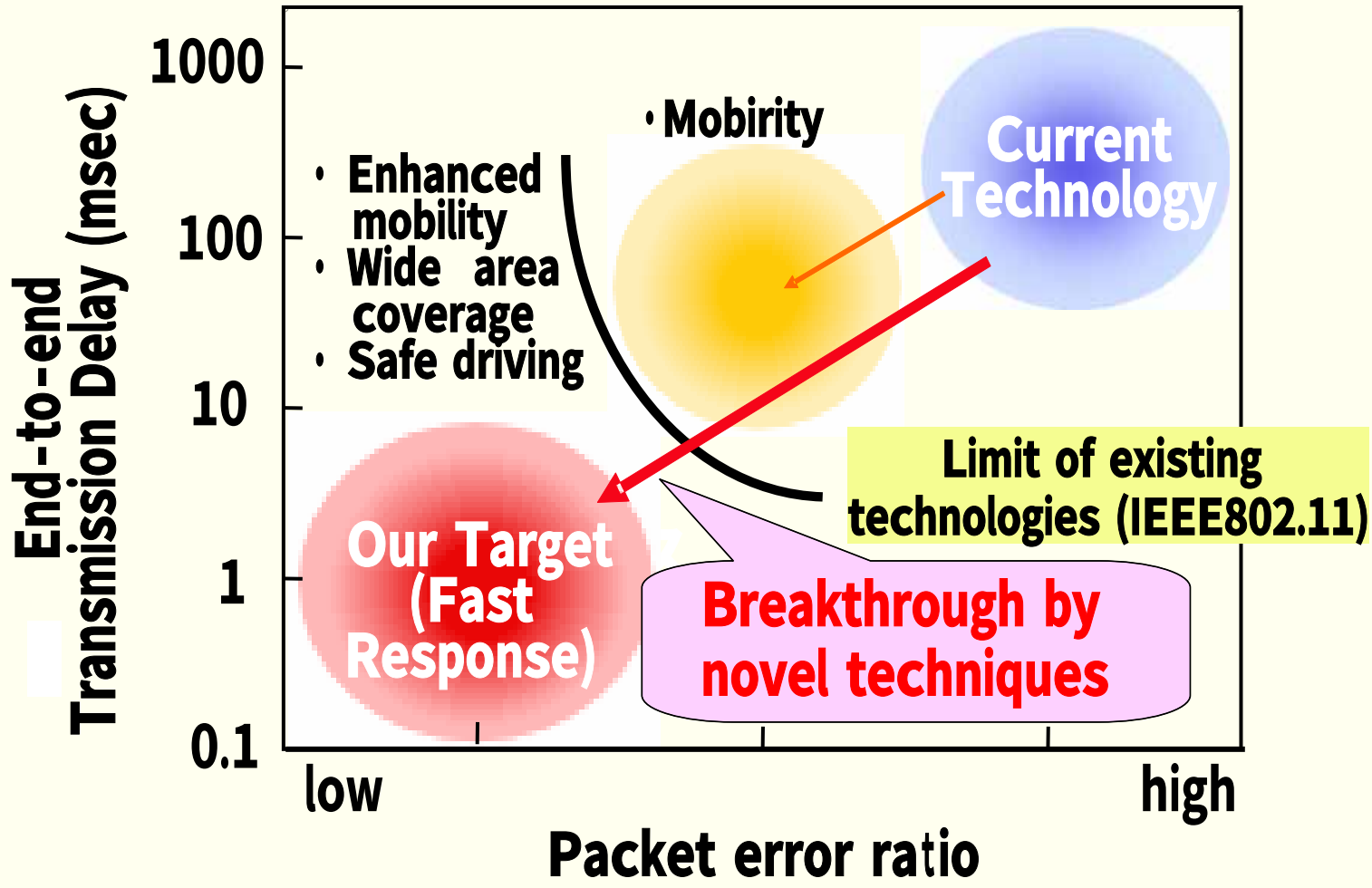
- **Existing Technology**

  The conventional MAC, CSMA/CA, used in the Wireless LAN (IEEE802.11) has a limit in transmission delay and packet delivery ratio, due to its control scheme based on the carrier sensing.

- **Our solution**

  We propose a new communication scheme called "Multi-carrier Multi-code Spread ALOHA (MM-SA)" that significantly reduces the transmission delay and improves the packet delivery ratio among vehicles.

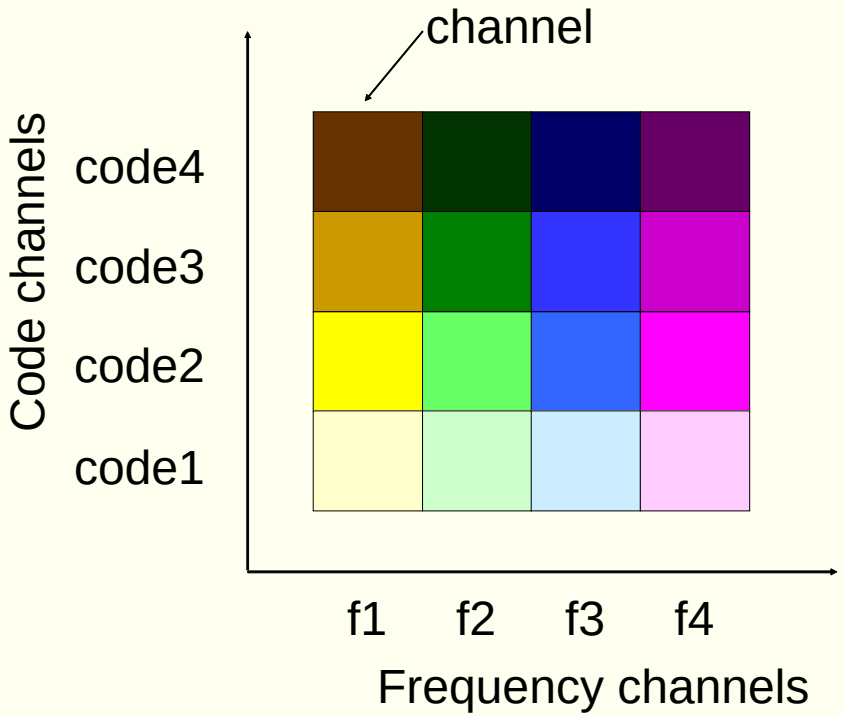
Our Technical Target



MM-SA: Multi-code Multi-carrier Spread ALOHA

Features

- MM-SA has the advantages of both CDMA※1 and FDMA※2.
- MM-SA realizes prompt and reliable communication even under the condition of high vehicle density by means of multiplexing in spreading code domain and frequency channel domain.



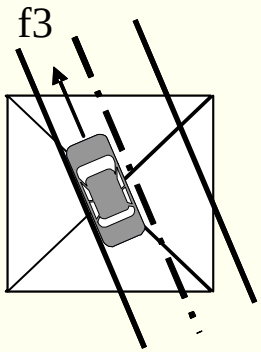
※1 CDMA: Code Division Multiple Access
※2 FDMA: Frequency Division Multiple Access

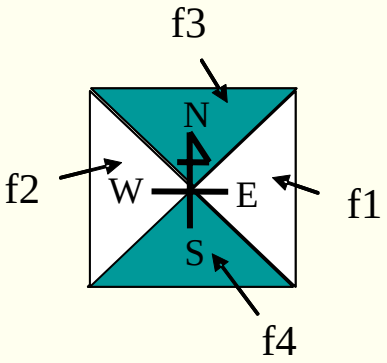
- Transmitted packet can be recovered regardless of packet collisions by using spreading code
- Communication traffic is diffused to multiple frequencies that helps to reduce signal collision probability.

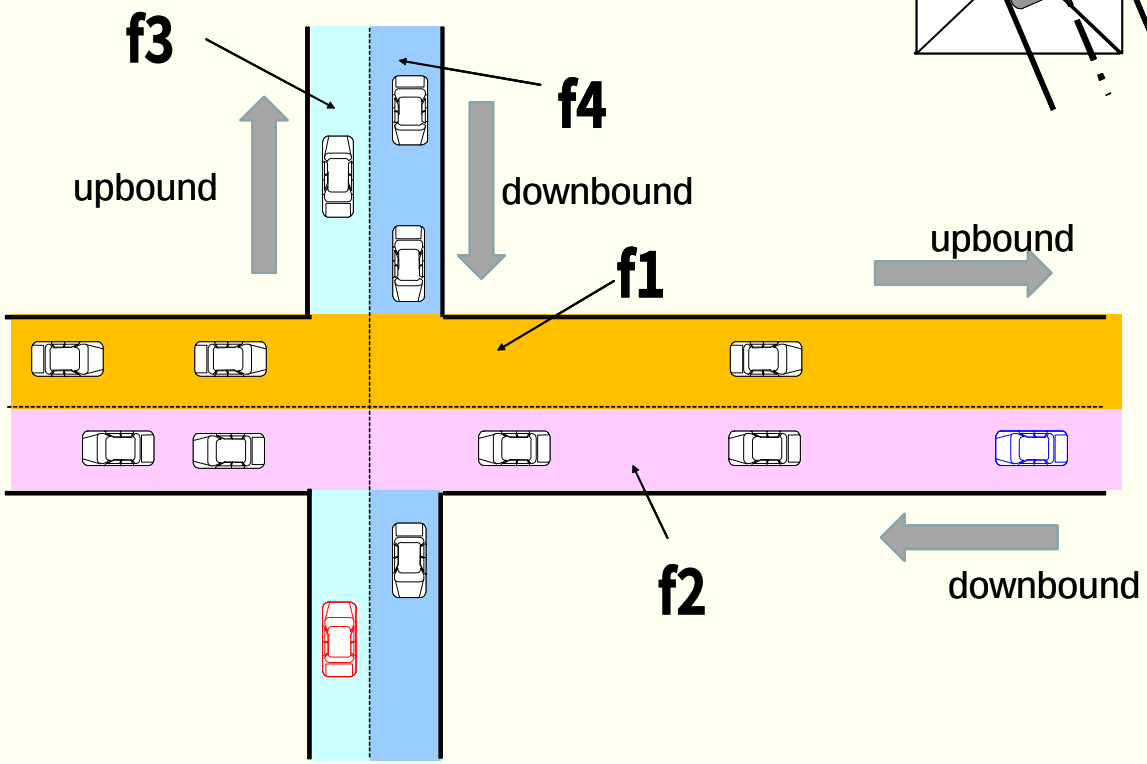
MM-SA: Frequency channel control (Topology aware channel assignment)

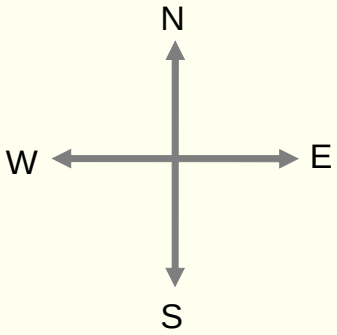
Frequency channel assignment example

street E-W/upbound ;	f1
street E-W/downbound ;	f2
street N-S/upbound ;	f3
street N-S/downbound ;	f4







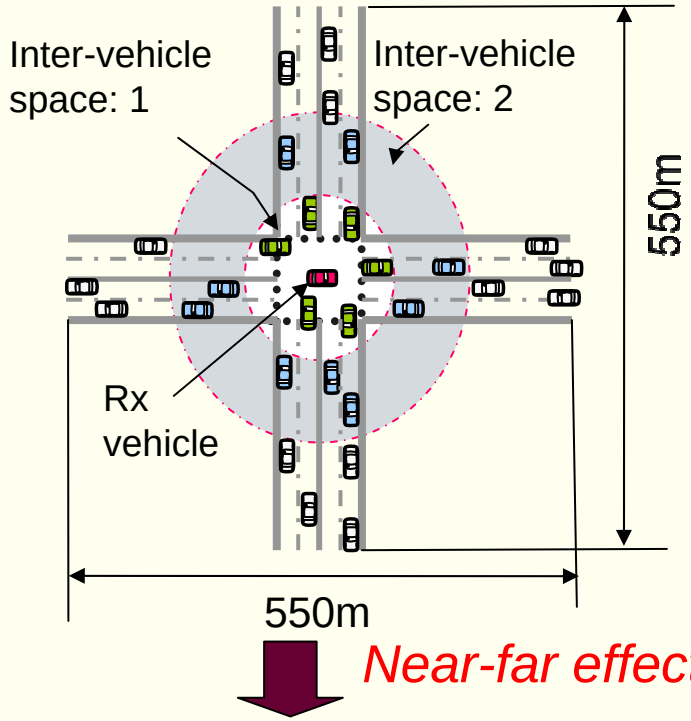


Characteristics of CSMA/CA and CDMA

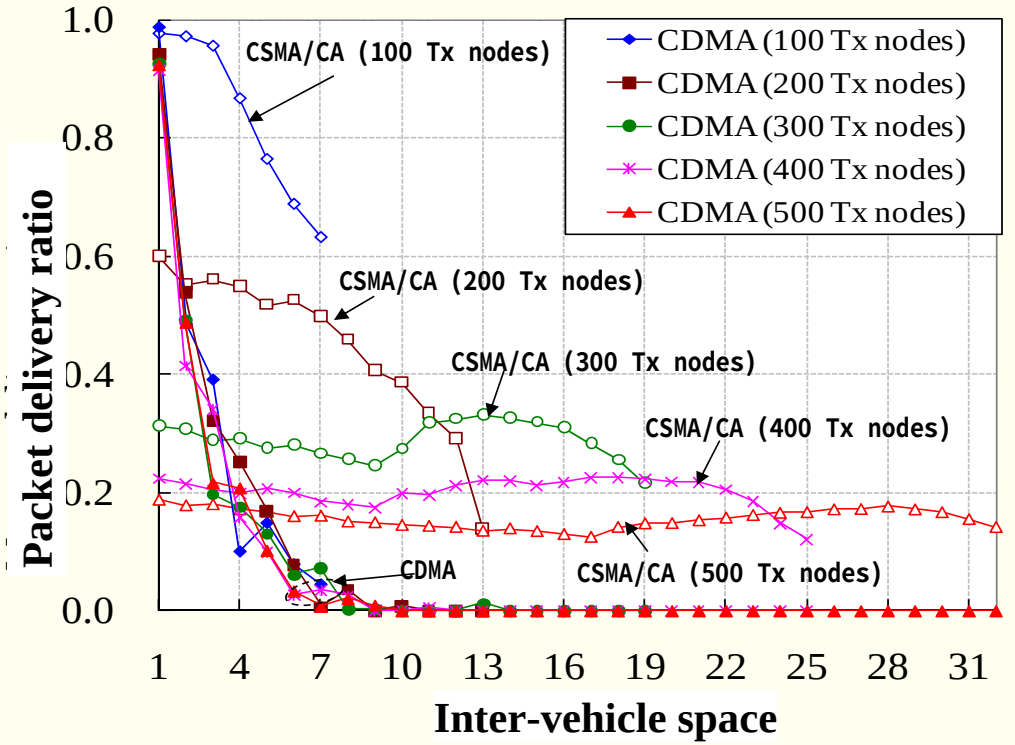
- 4.096 MHz channel, 5.8GHz
- CSMA/CA :Contention window= [1,256]
- CDMA: Spreading factor= 7

Packet transmission delay

The number of Tx vehicles	100	200	300	400	500
CSMA/CA [ms]	4.9	72.4	133	168	193
CDMA [ms]	1.9	1.9	1.9	1.9	1.9



Near-far effect



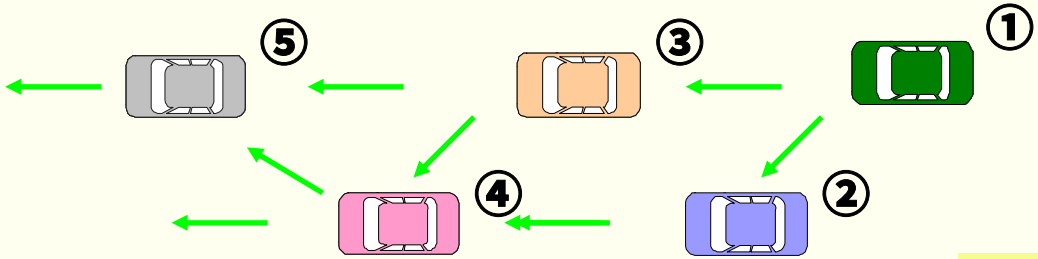
Prompt and reliable information exchange among near vehicles, without being affected by the number of vehicles

MM-SA: Packet Forwarding Scheme

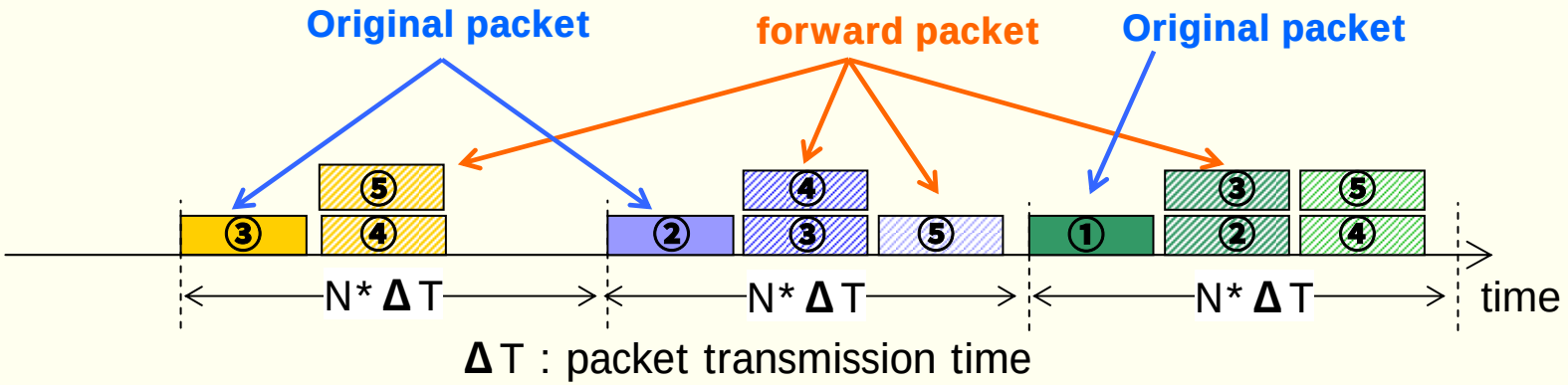
～Enabling vehicles to be aware of existence of far vehicles～

To avoid broadcast storm ;

- forwarding packets over a limited area determined by the vehicle's location. (e.g. 100m x 10m)
- no forwarding duplicated and/or outdated information.
- adequate scheduling of packet transmissions.



Transmission scheduling



ΔT : packet transmission time

ASV and accident scenarios

ASV defines the requirements for various safe driving scenarios, in concrete.

ASV(Advanced Safety Vehicle)

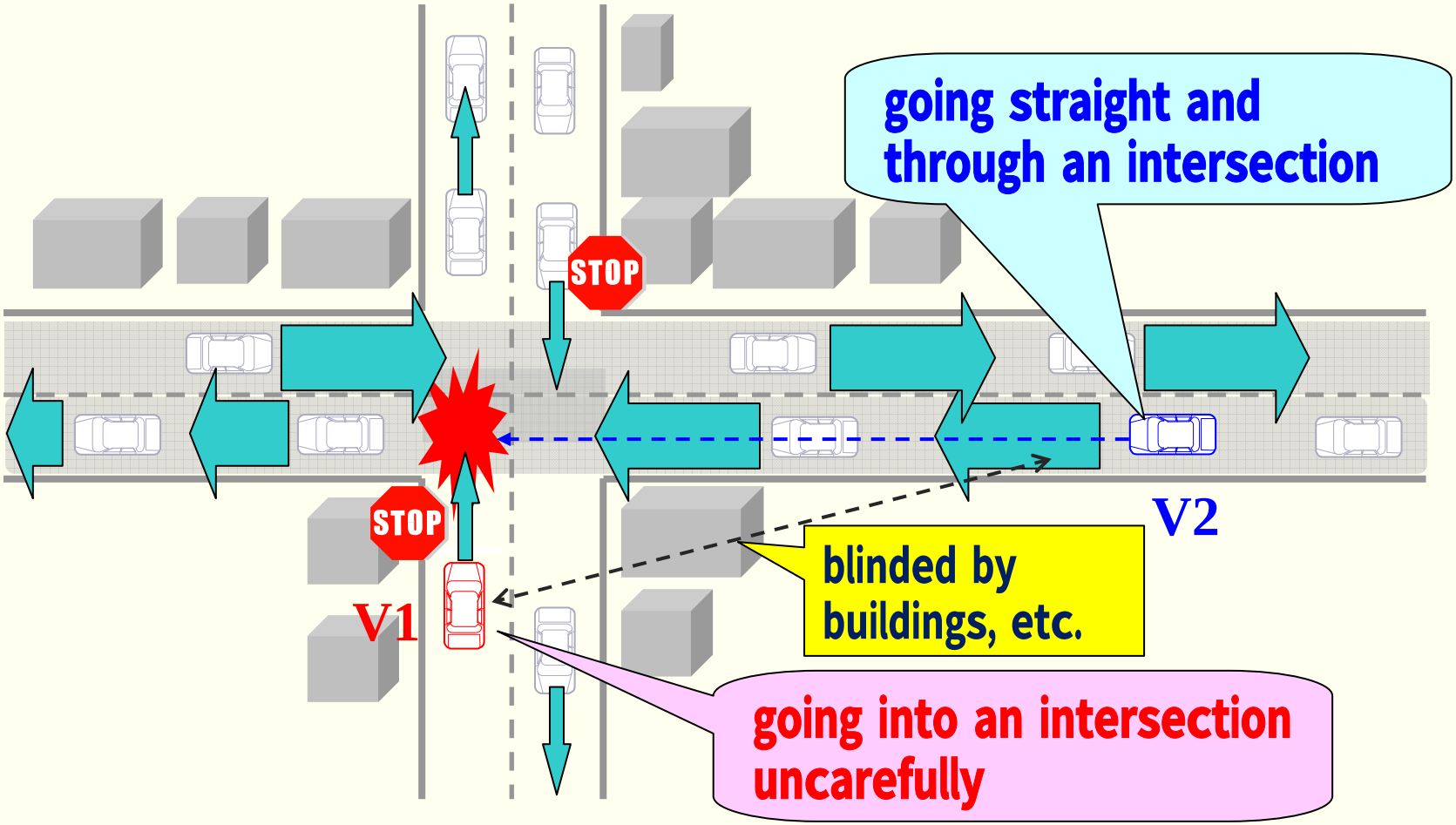
The program assisted by automotive manufacturers and the ministry of land infrastructure and transport in Japan.
(16 companies, including Volkswagen and Mercedes-Benz)

Major scenarios

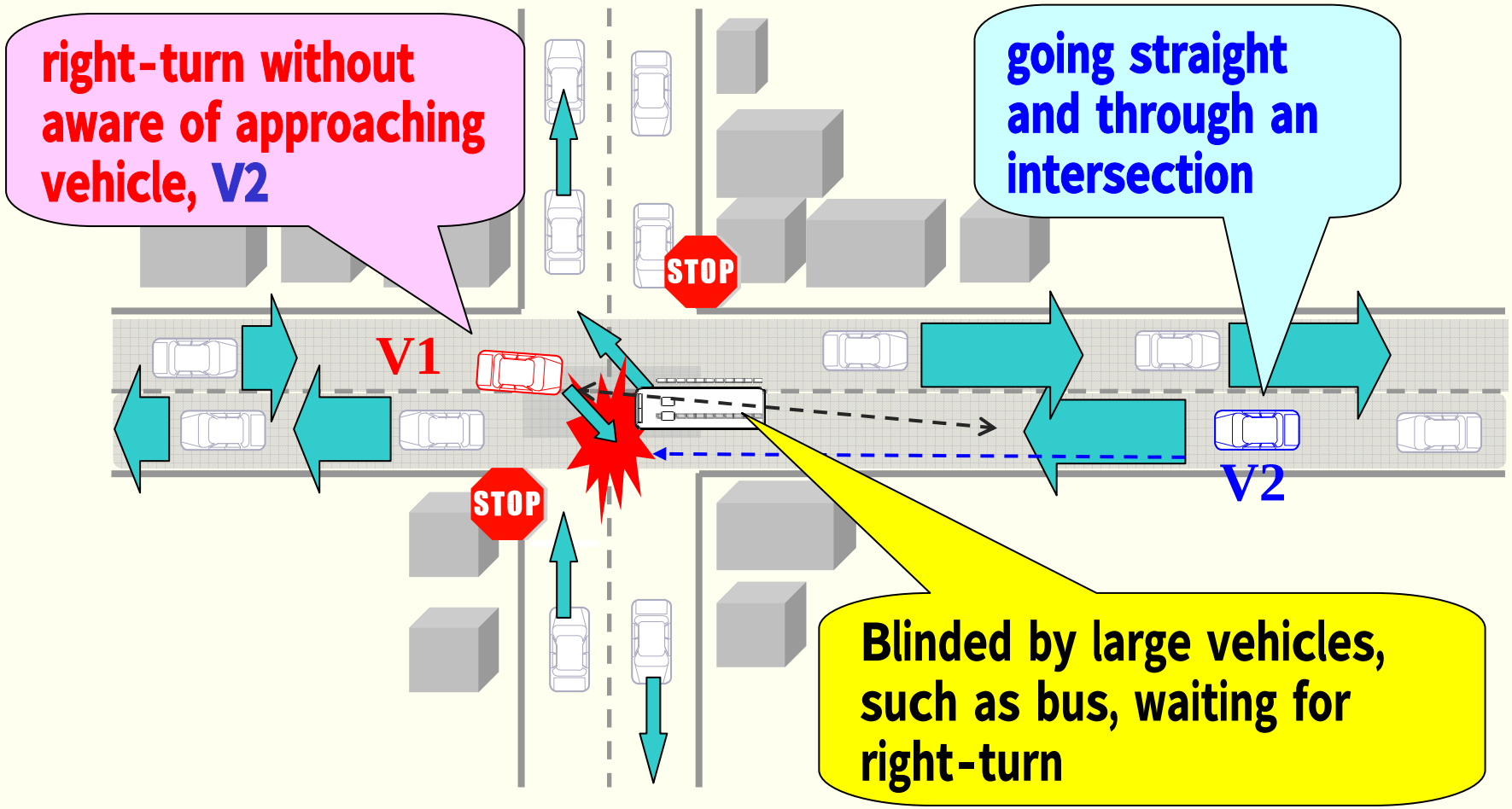
- *Head-on collision at an intersection*
- *Right-turn collision at an intersection*
- *Left-turn collision at an intersection*
- *Rear-end collision*

and so on

Head-on collision scenario

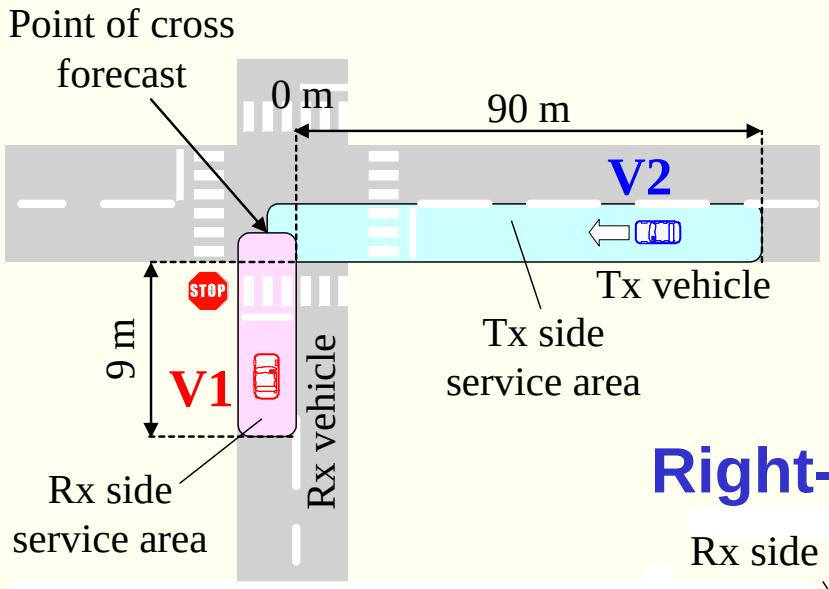


Right-turn collision scenario



ASV requirements

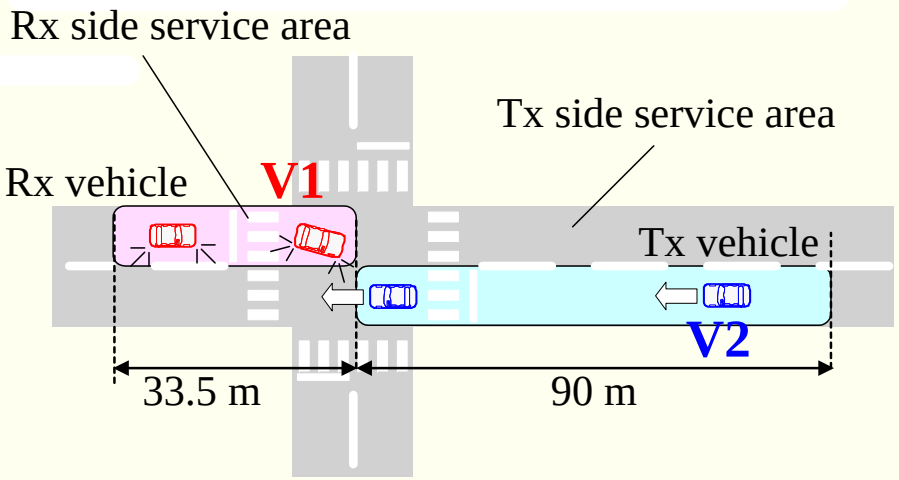
Head-on collision avoidance



Total number of vehicle : 88
Vehicle density :
average 19.4 m (70Km/h)
Packet transmission cycle:
100msec (70Km/h)

Packet Delivery Ratio ≧80%

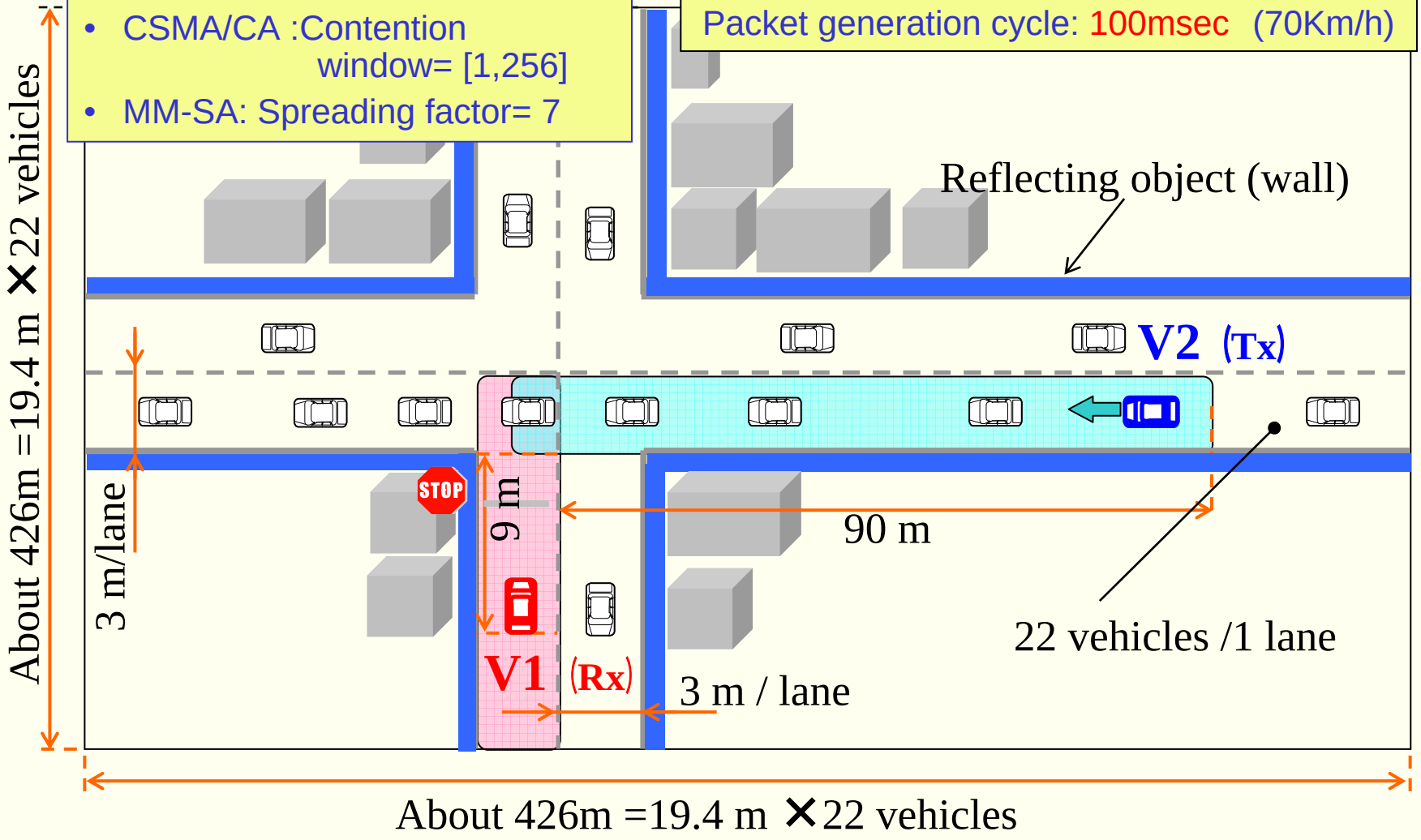
Right-turn collision avoidance



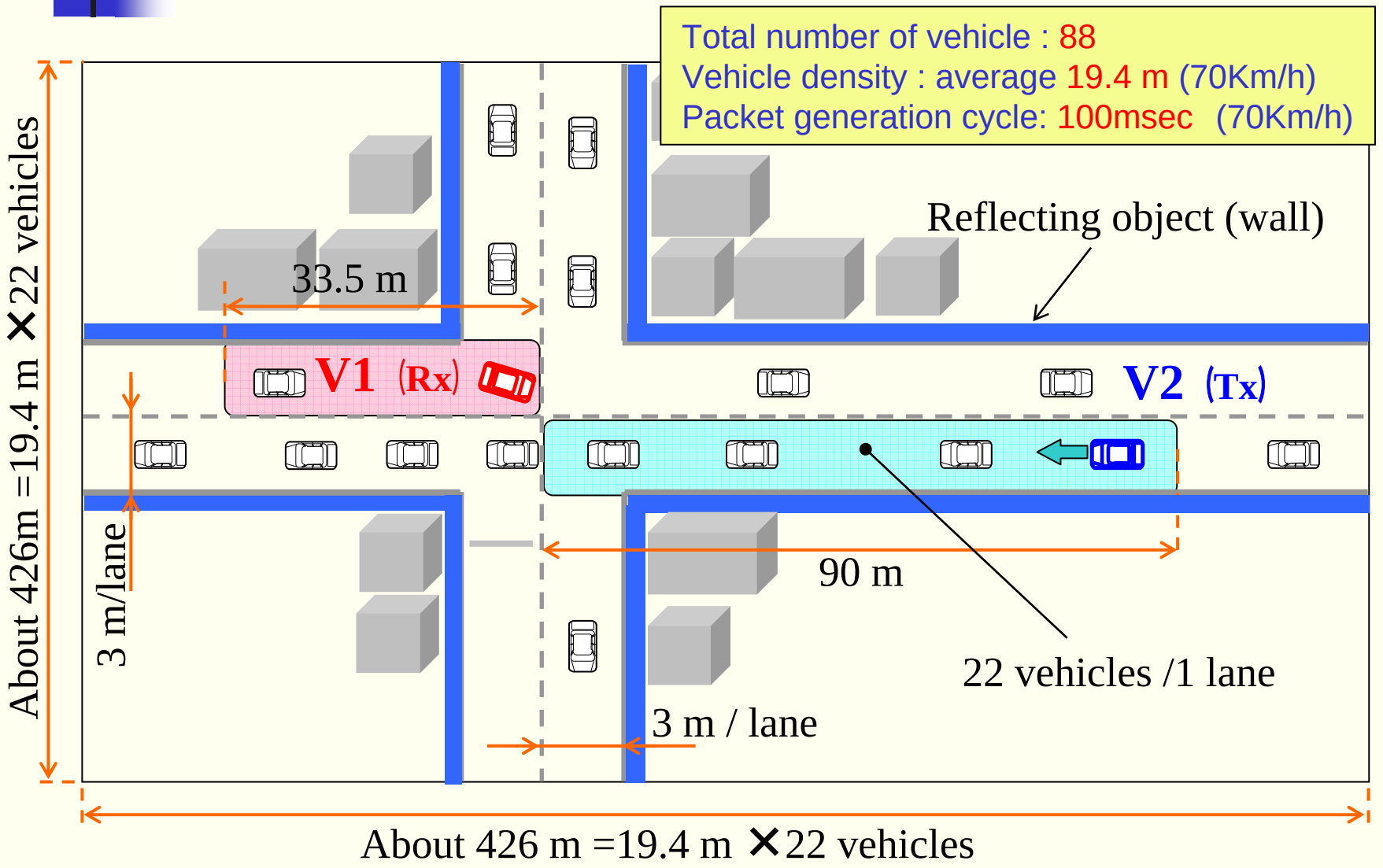
Simulation condition
～ Head-on collision scenario ～

- 4.096 MHz 4ch, 5.8GHz
- Modulation: π/4-shift QPSK
- CSMA/CA :Contention window= [1,256]
- MM-SA: Spreading factor= 7

Total number of vehicle : 88
Vehicle density : average 19.4 m (70Km/h)
Packet generation cycle: 100msec (70Km/h)



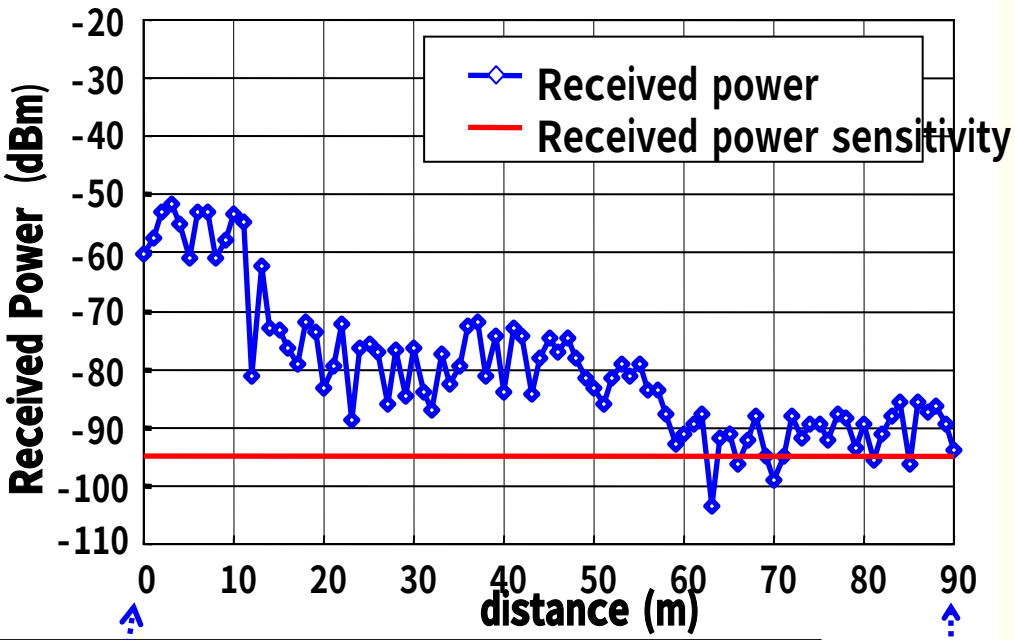
Simulation condition
～ Right-turn collision scenario ～

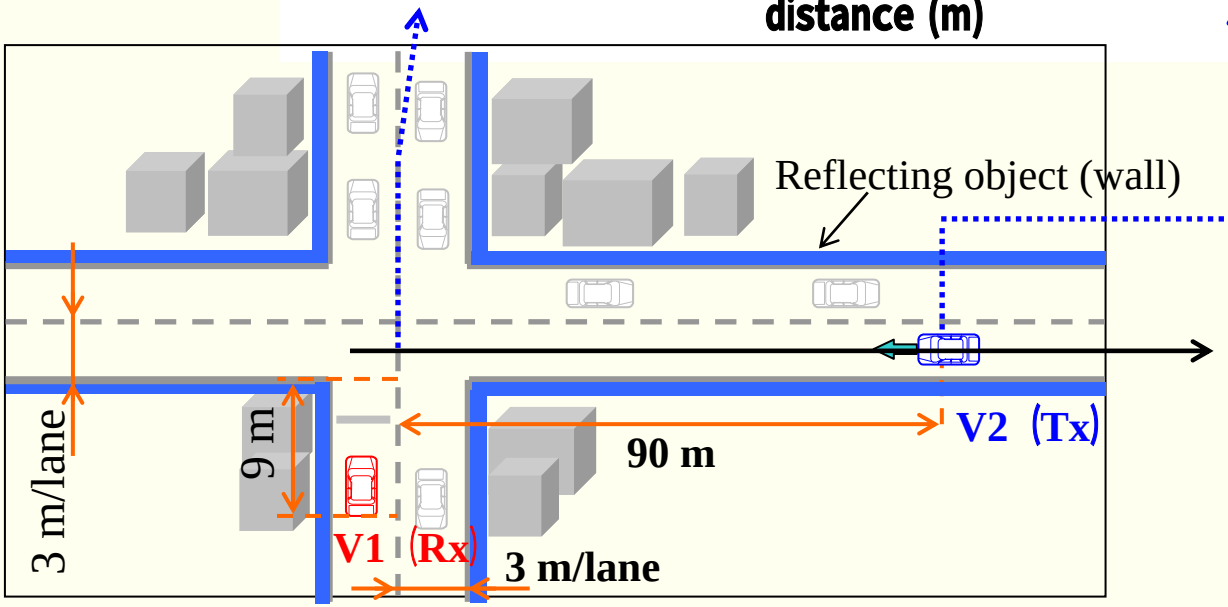


Received power characteristic (Non Line Of Sight)

Radio propagation model:
ray-tracing
Antenna height: 1.5 m

V2's signal strength is partially below sensitivity level, when V2 is 65 meters or further from the junction.



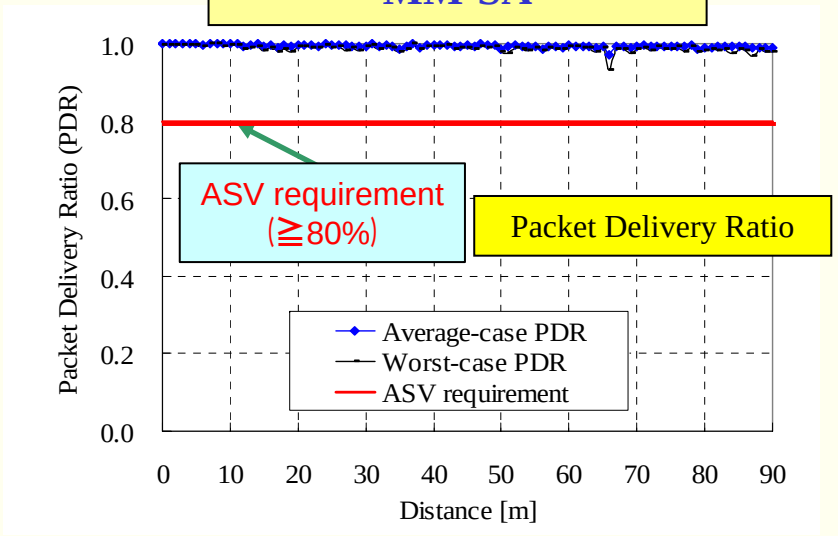


Packet forwarding is necessary !

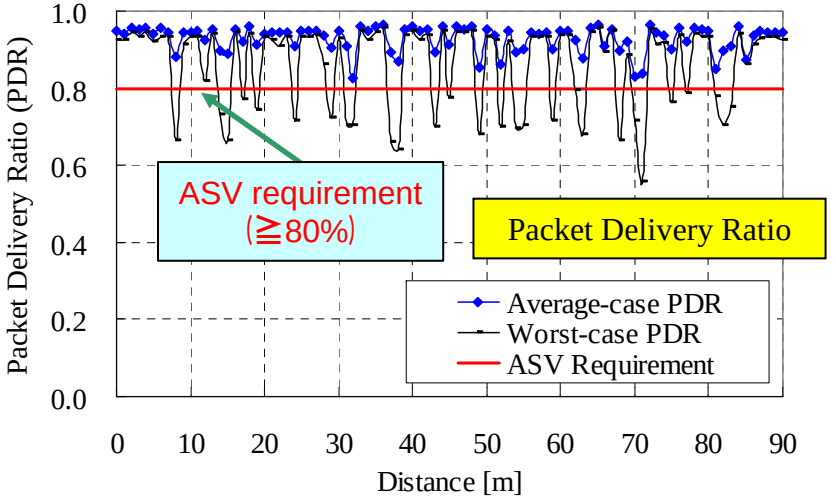
Simulation results

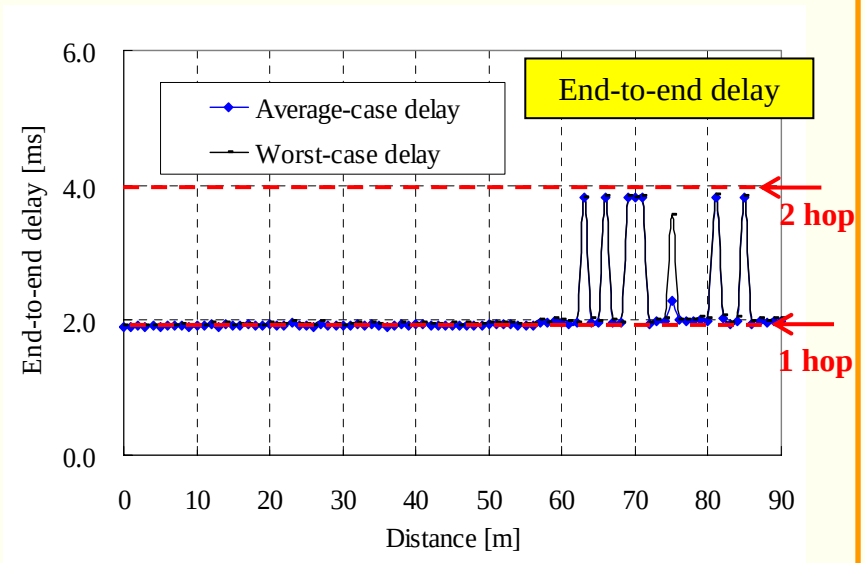
- Head-on collision avoidance , 88 Vehicles, 1 lane / direction -

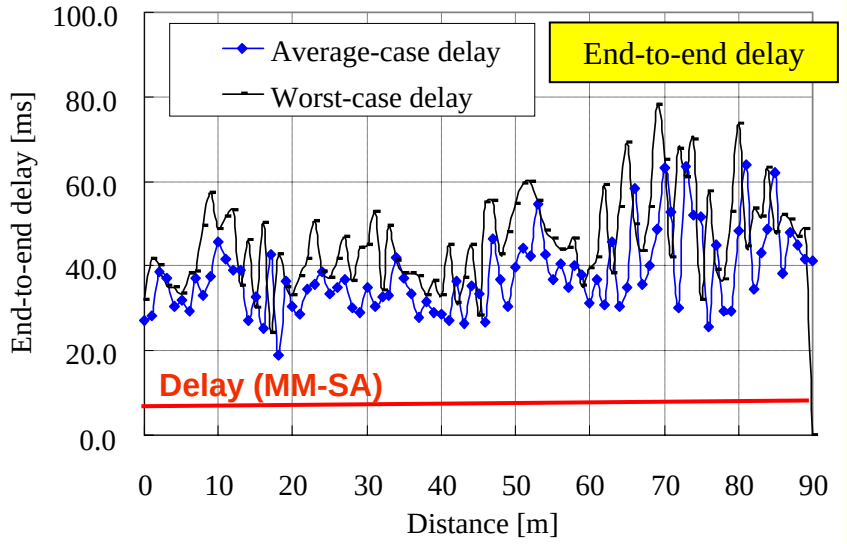
MM-SA



CSMA/CA



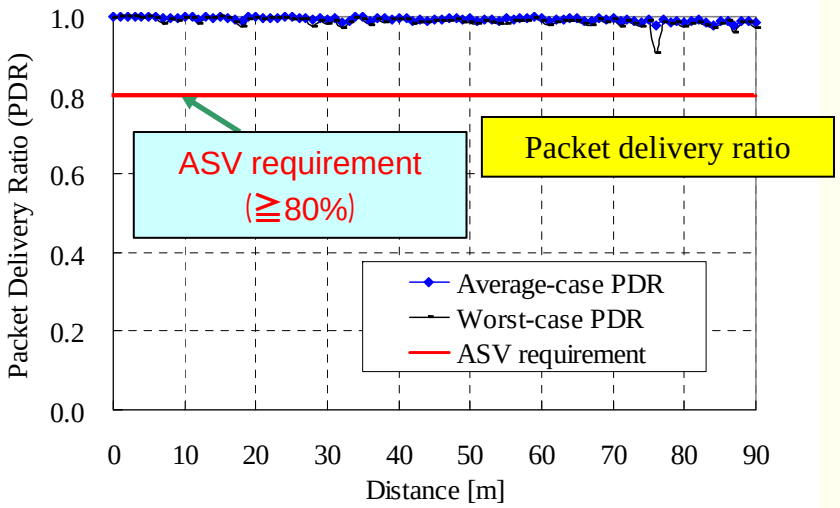


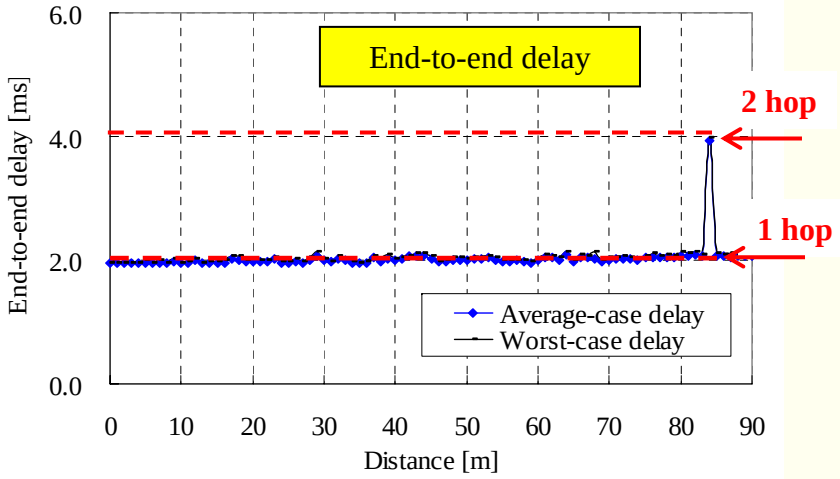


Simulation results

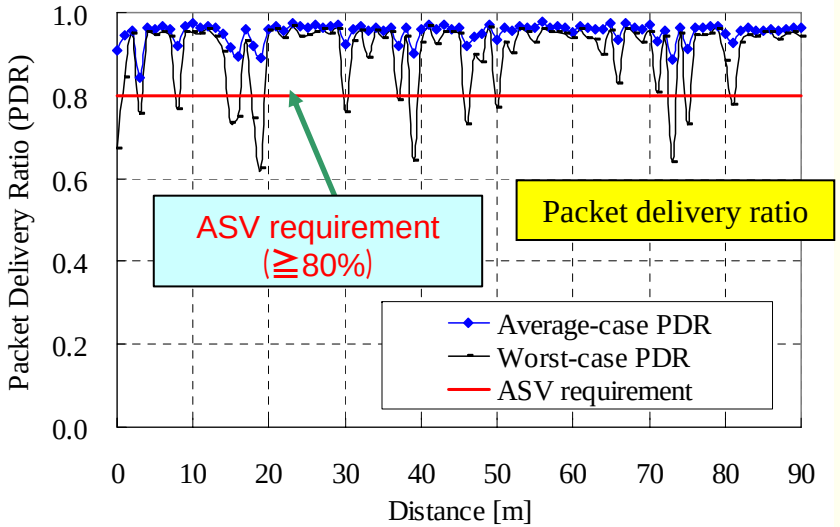
- Right-turn collision avoidance, 88 vehicles, 1 lane / direction -

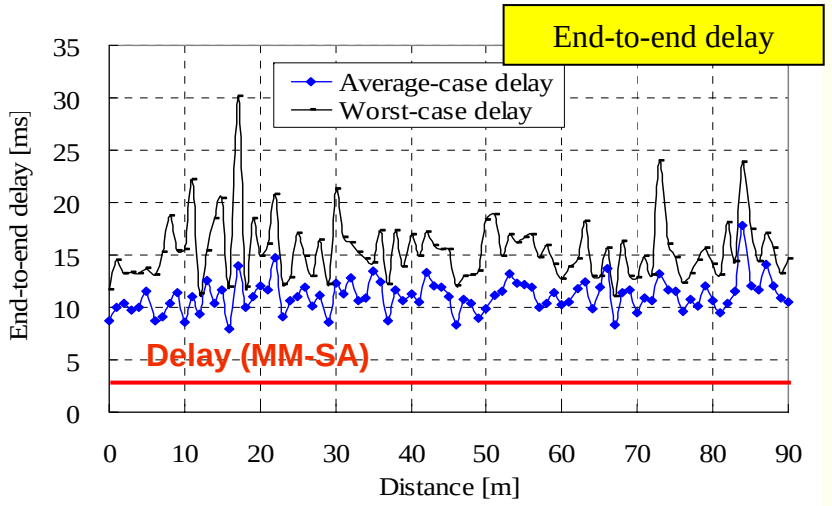
MM-SA





CSMA/CA





Prototype System

- All the core technologies such as spread spectrum, frequency control and packet forwarding are implemented in the prototype.
- The prototype achieves the forwarding delay below one msec.

Specifications

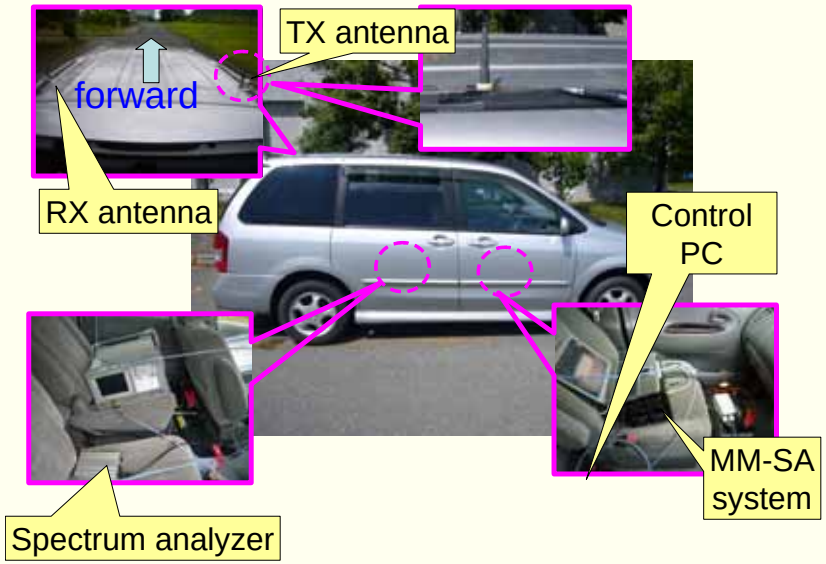
Parameter	Specification
Frequency	5780, 5790, 5820, 5830MHz
Chip Rate	2.048Mcps
Bit Rate	292kbps
Spreading Factor	7
Modulation	π/4-shift QPSK
Data Detection	delay detection

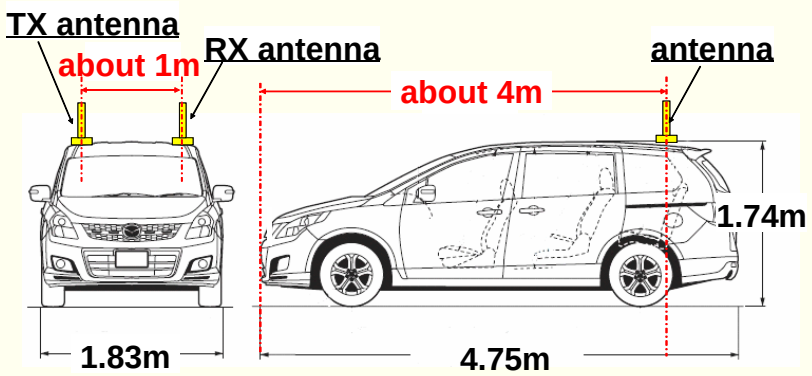
Prototype System

(Size: 323mm×260mm×128mm)

Field Experiment

Prototype and antenna setup





Measure the radio propagation and packet error rate characteristics under the non line-of-sight condition.

Experiment at an intersection

Conclusion

- Develop MM-SA scheme for inter-vehicle communication to assist safe driving
- Realize fast response and highly reliable transmission of vehicle information

For further study

- Field experiment on actual roads
- Further performance evaluation in scalability (in the numbers of vehicles), and in other accident scenarios
- Comparison with the other channel access schemes, e.g. Timing Synchronized CSMA and Distributed TDMA etc.
- Comparison with ITS Forum RC-006 (700MHz band)

Thank you for your attention !

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