

Intervehicle Communication: Effects on Safety and Autonomy

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Presentation Outline

- Near-term trends
- Some recent investigations on V2V
- On-road and off-road autonomy
- A vision towards the future

Autonomy

Autonomy in vehicles: The ability to drive with no (or limited) interaction with humans.

Safety, convenience and enjoyment

- Long distance issues
- Short distance issues

Short distance information issues in autonomous cars

On road:

- Obstacle avoidance
- Lane change
- Intersection collision avoidance
- Lane keeping
- Convoying
- Stop-and-go in-city

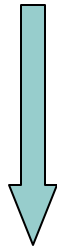
Short distance information issues in autonomous cars

Off road and non-roadway:

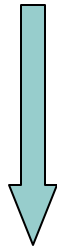
- Obstacle avoidance
- Convoying
- General map information
- Task specific applications
 - Test systems
 - Airports
 - Forrest fires
 - Maintenance, re-supply

Effect of wireless communication

- Wireless cannot help

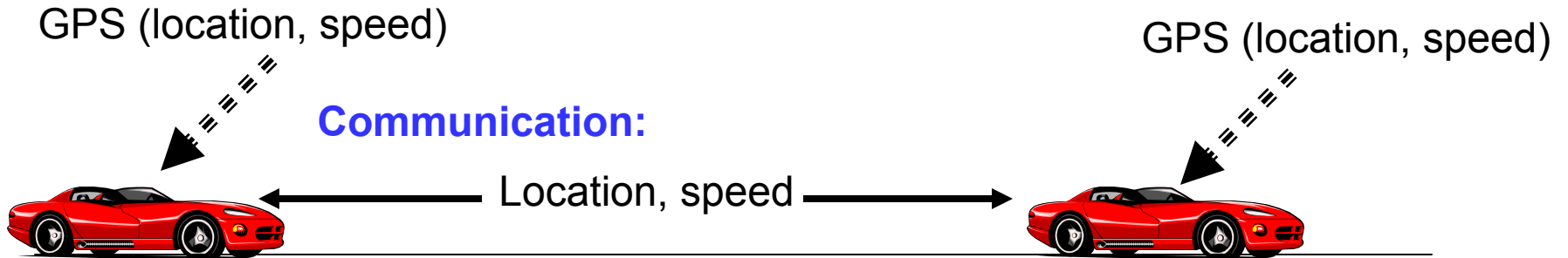


- Wireless is useful

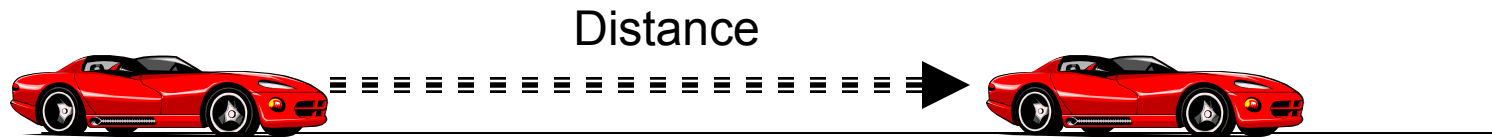


- Wireless is necessary

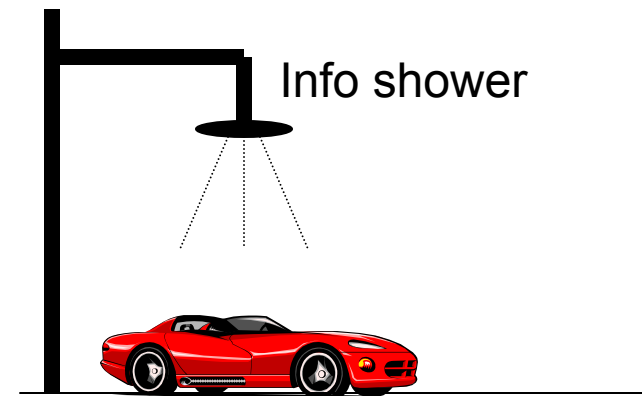
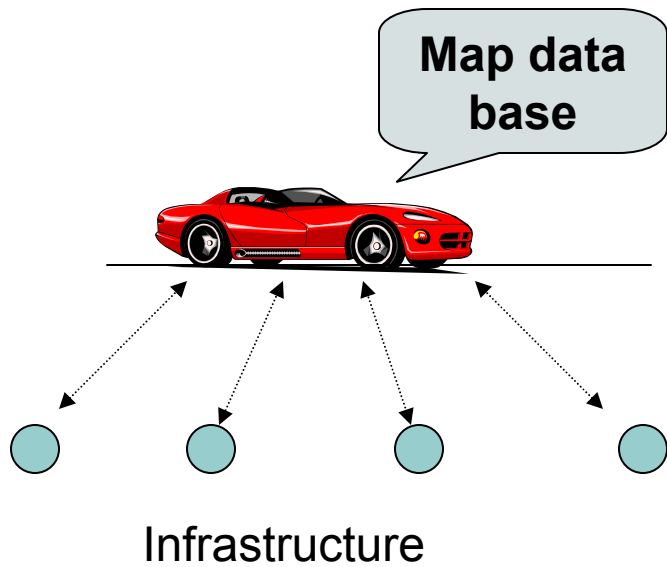
Examples:



Measurement:



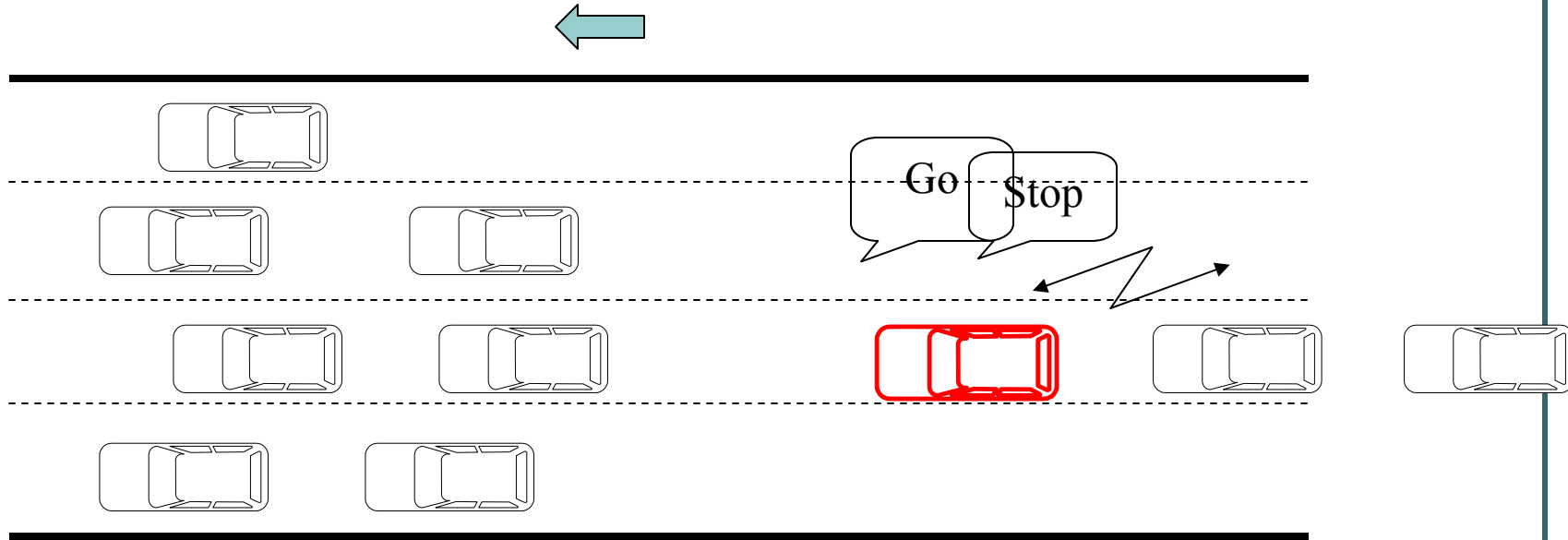
Examples:



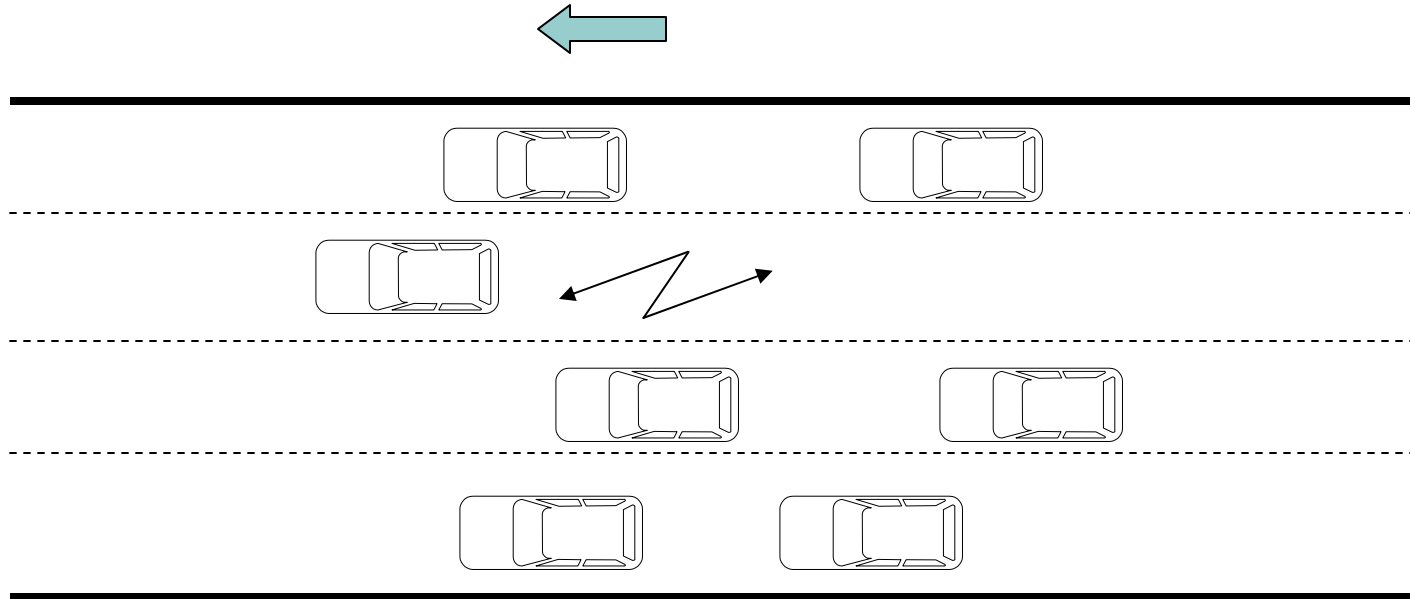
Examples of Inter-vehicle communication System

NO	APPLICATIONS	SERVICES	SERVICES BAND	RANGE
1	Stop & go Adaptive Cruise Control	Take over automatic braking and driving, when vehicles are in traffic jam	Millimeter-wave (59-66GHz)	~30m
2	Cooperative driving	Cooperative driving by exchanging respective cruising data (position, velocity etc.)	Millimeter-wave	>150m
3	Hazard warning (Accidents, obstacles)	Obstacle warning Stopped vehicle warning Slowing down warning	Millimeter-wave	<600m
4	Merge & lane change warning	Safe and smooth lane change and merging with communication	Microwave	~200m
5	Intersection & winding curve collision warning	Solve no line-of-sight problems for safe and smooth cruise	Microwave	~200m
6	Inter/intra-platoon communication	Ad hoc communication between vehicles	Microwave	2m~200m

Stop & Go Adaptive cruise control



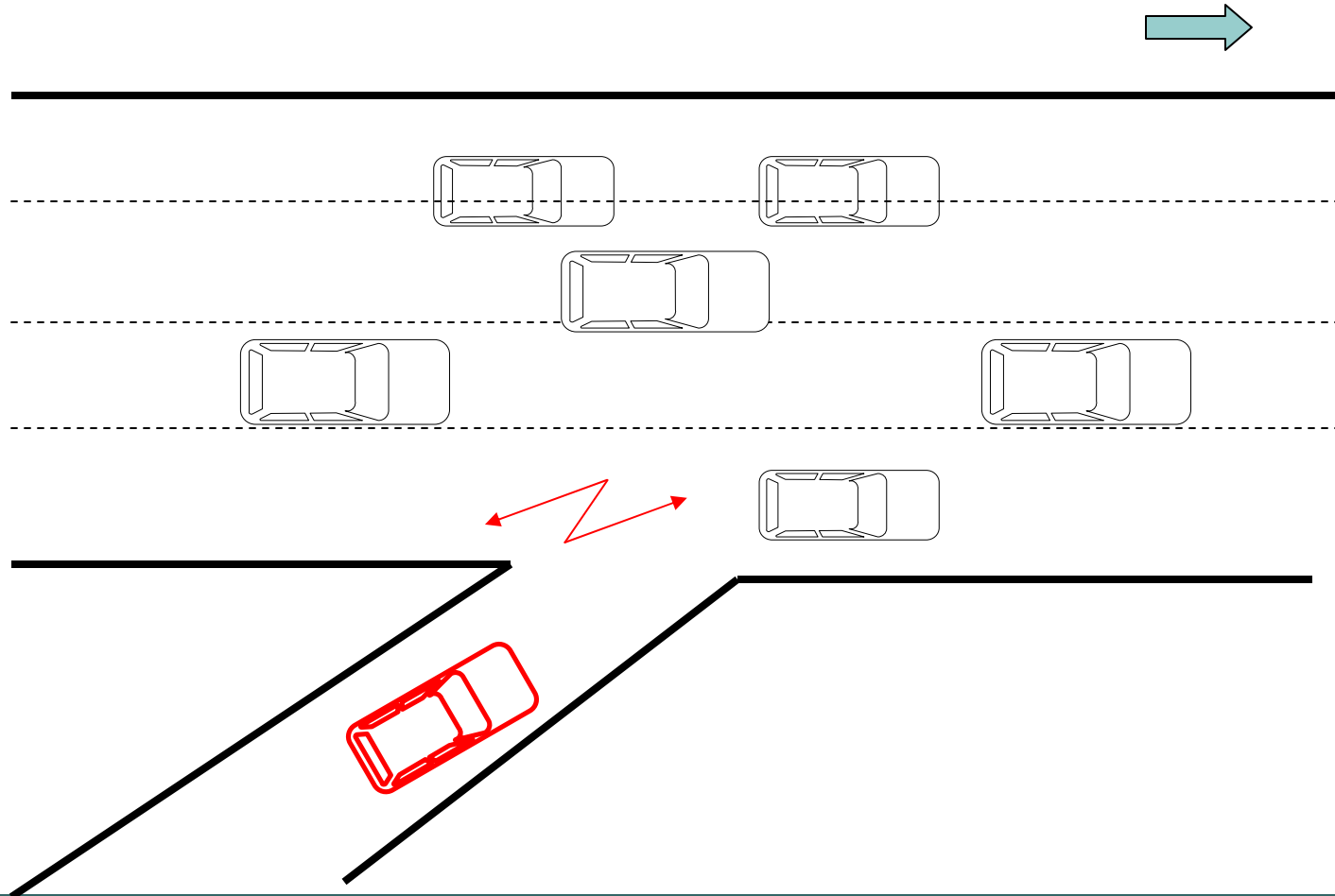
Cooperative Driving



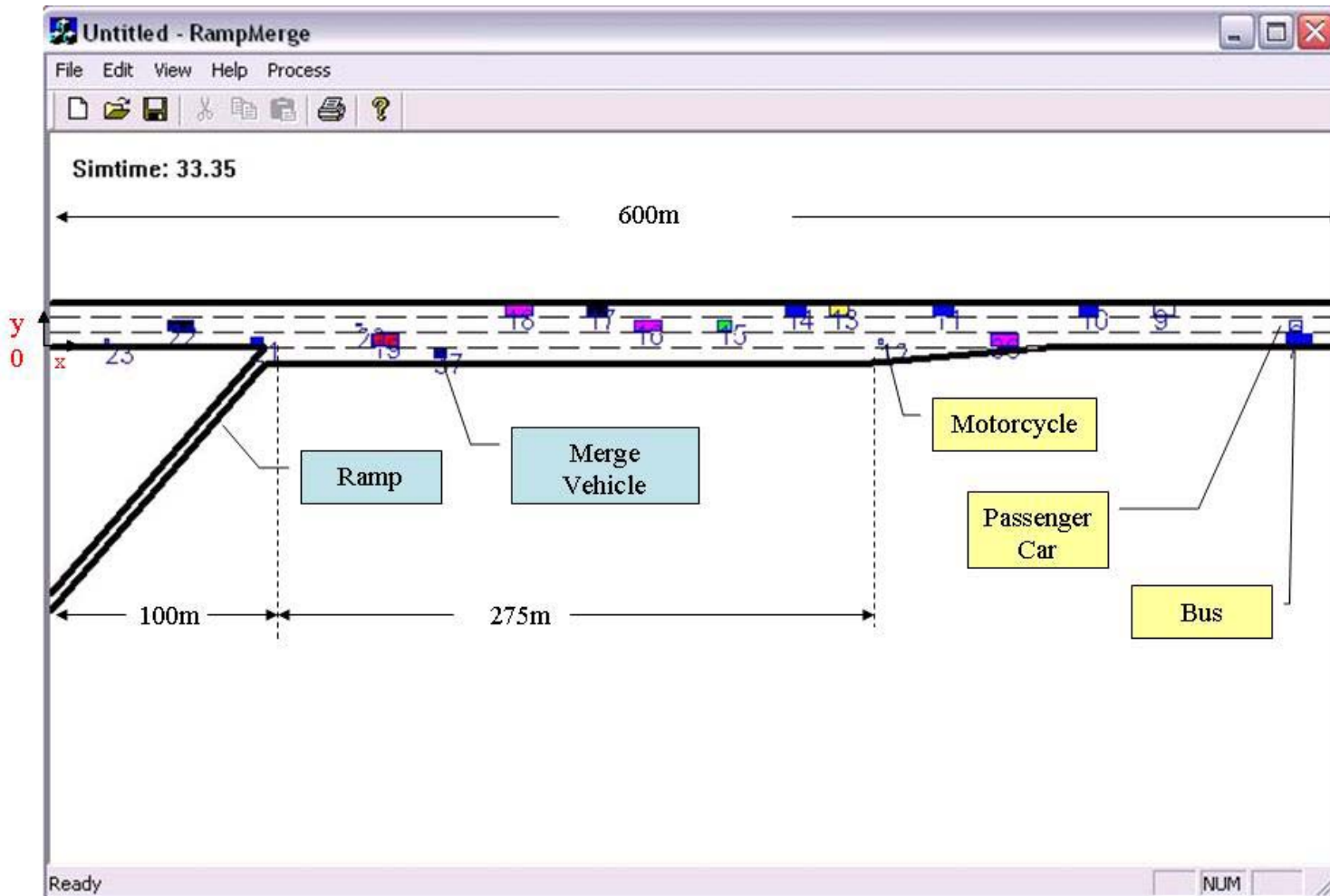
Hazard warning



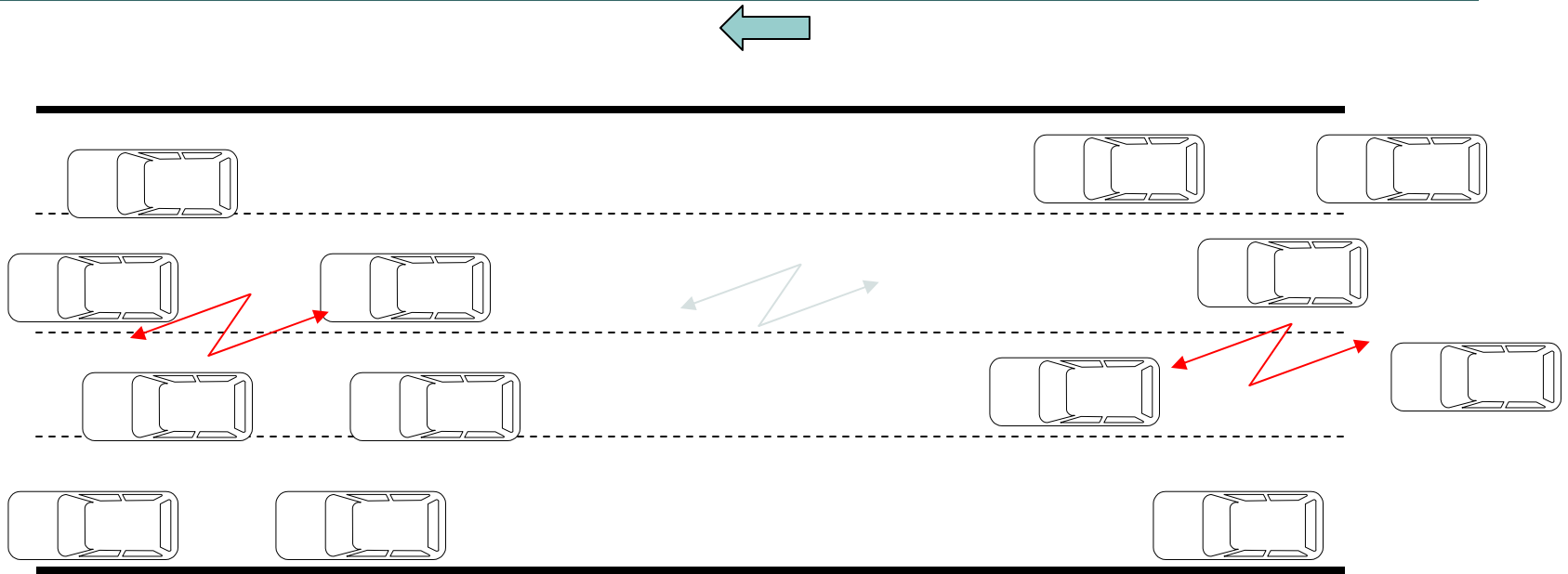
Merging and lane changing warning



Screenshot of ramp merge simulator using inter-vehicle communication



Inter/intra-platoon communication



Some recent studies:

- Single hop communication
- Multiple hop communication
- Intersection collision warning modelling

Messages Considered

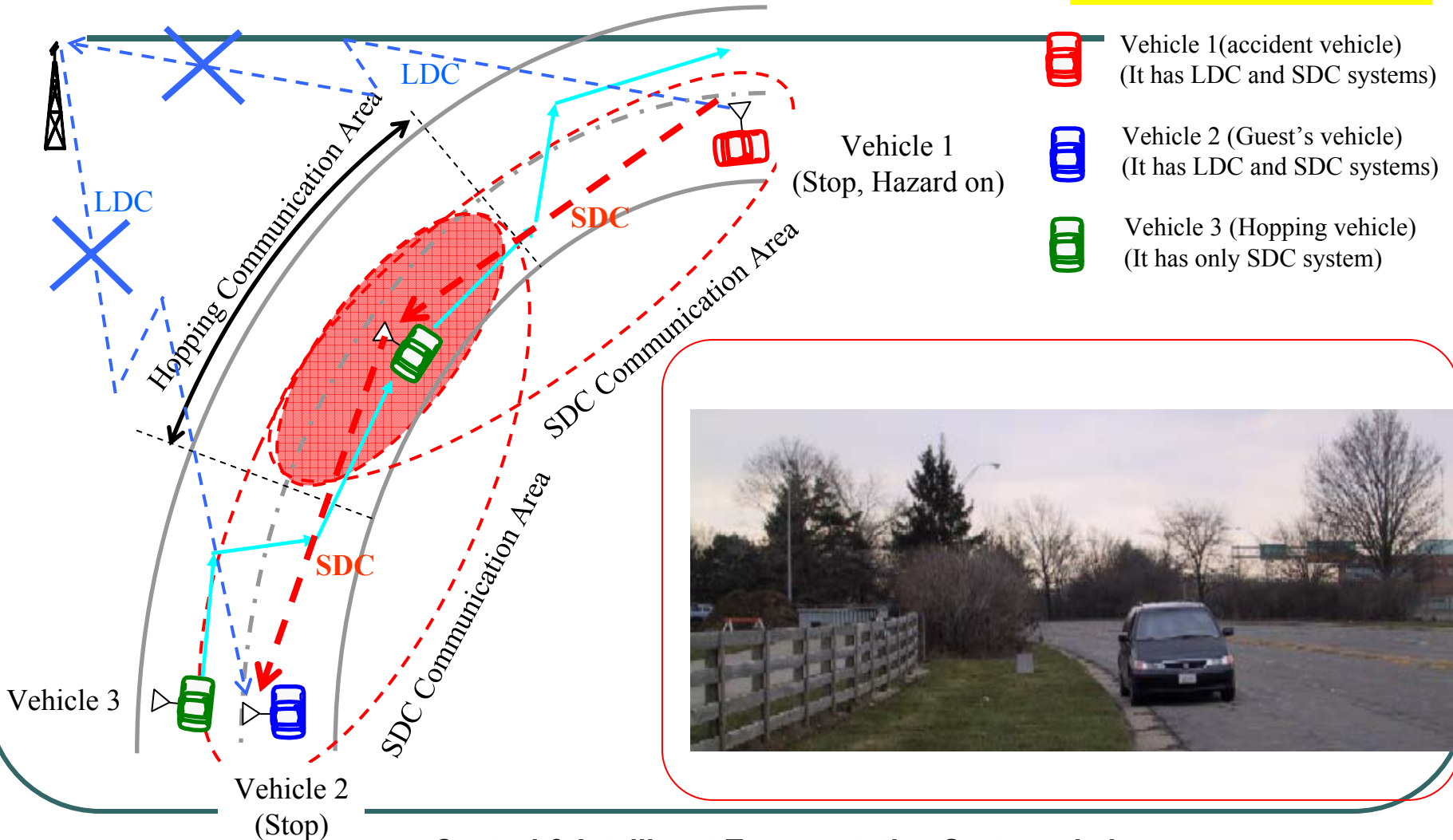
1. Brake deployed	C
2. Air-bag deployed	R
3. Tire burst	C,R
4. ABS deployed	C
5. Turn signal (R)	C
6. Turn signal (L)	C
7. Steer (L)	C
8. Steer (R)	C
9. Backup	C
10. Accelerate	C
11. Obstacle	R
12. Road Closed	R
13. Detour	R
14. Slippery surface	C,R
15. Low visibility	R
16. Off-Road status	C,R
17. Distress	R
18. Slow Traffic	R
19. Continues brake signal	R
20. Message relay	R
21. Written chat	R
22. Other	
23.	

Curve Hopping

- Hopping measurement at curve

Place : SDC Received Power \geq LDC Received Power

SDC at 5.9 GHz
LDC at 220 MHz



Blind Intersection

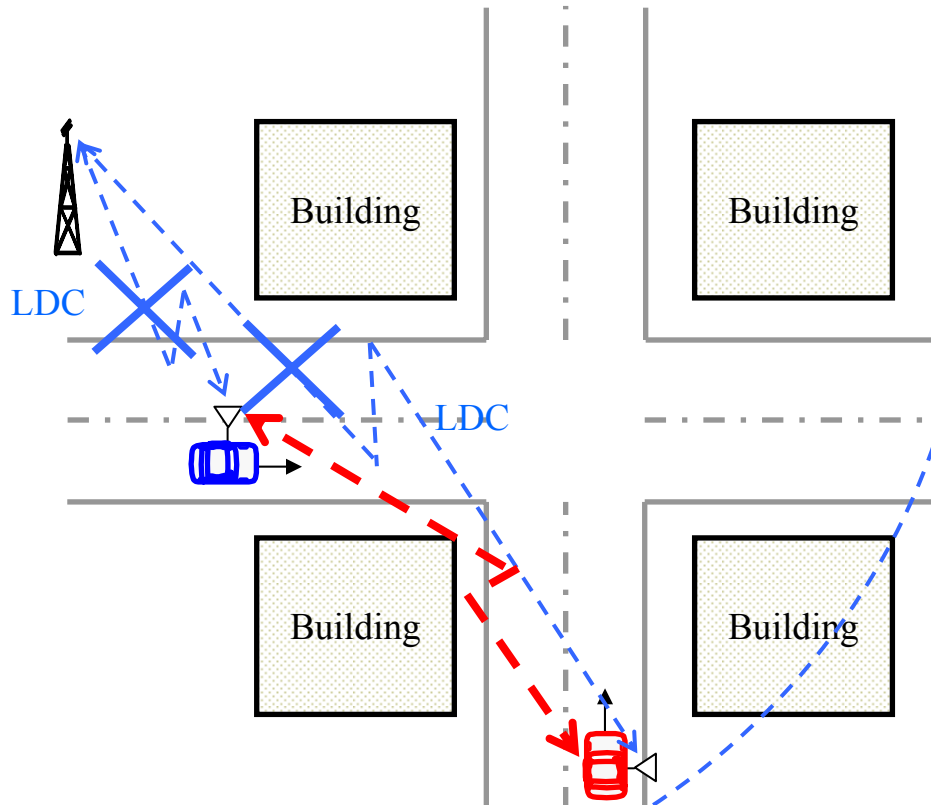
- Head encounter accident prevention at blind intersection



Vehicle 1 (Accident vehicle)
(It has LDC and SDC systems.)

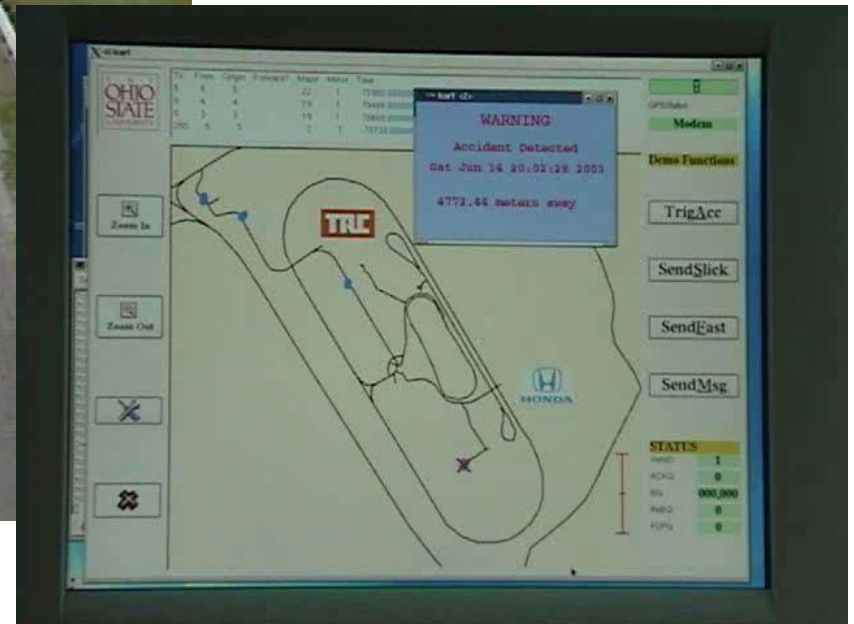


Vehicle 2 (Guest's vehicle)
(It has LDC and SDC systems.)



1. Vehicle 1 and vehicle 2 runs each other.
2. Vehicles can't watch each other, because of building. Vehicles transmits vehicle location each other.
3. Vehicle receives packet and tell driver warning.

Network demonstration (IV'03 in Ohio 2003)



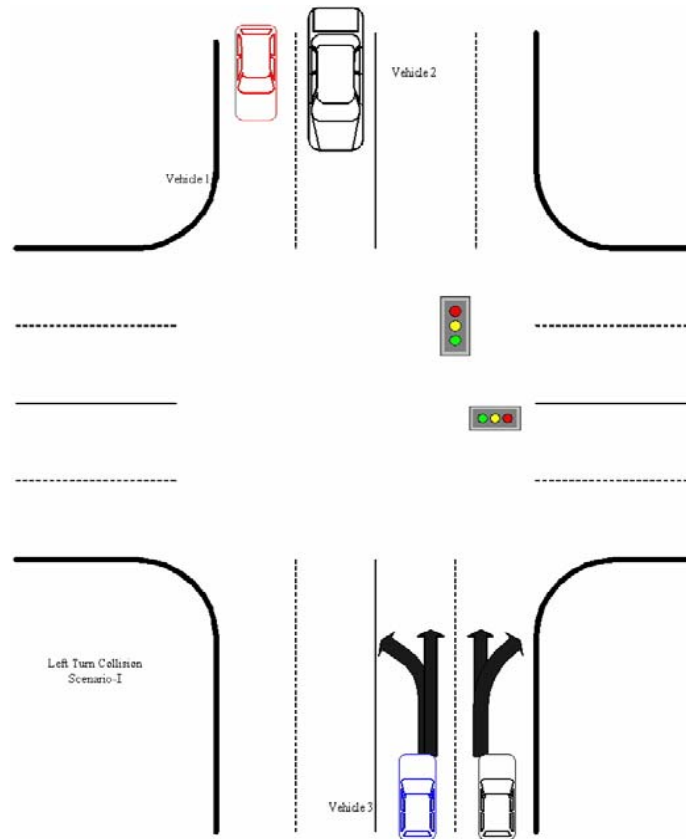
Both displays in the vehicle



A recent project:

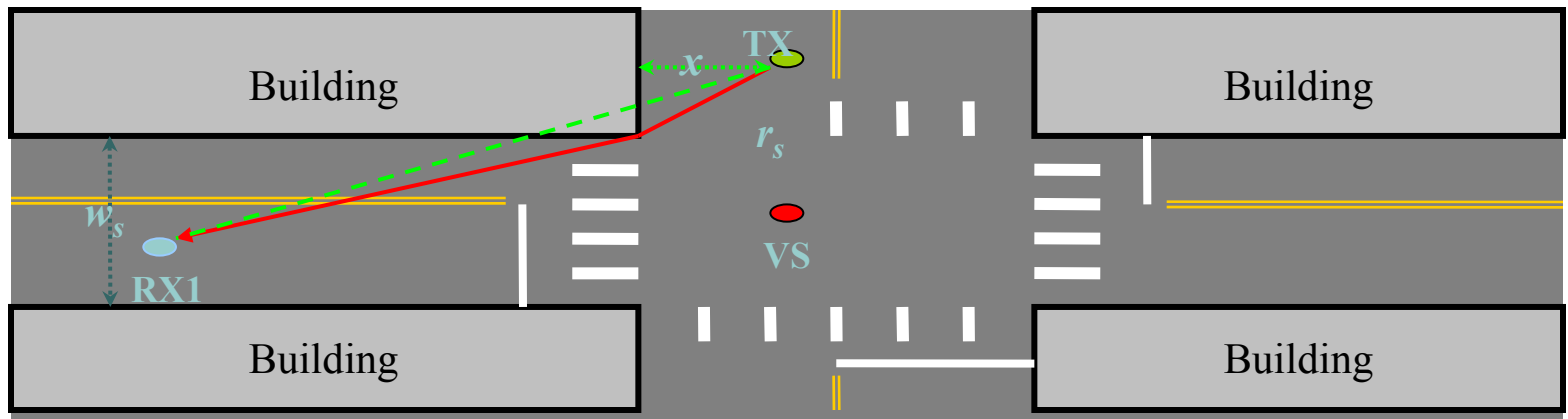
**Car-to-car info (with possible
repeater) for intersection safety.
Testing of hardware, development of
simulator.**

Intersection collision: The left-turn case

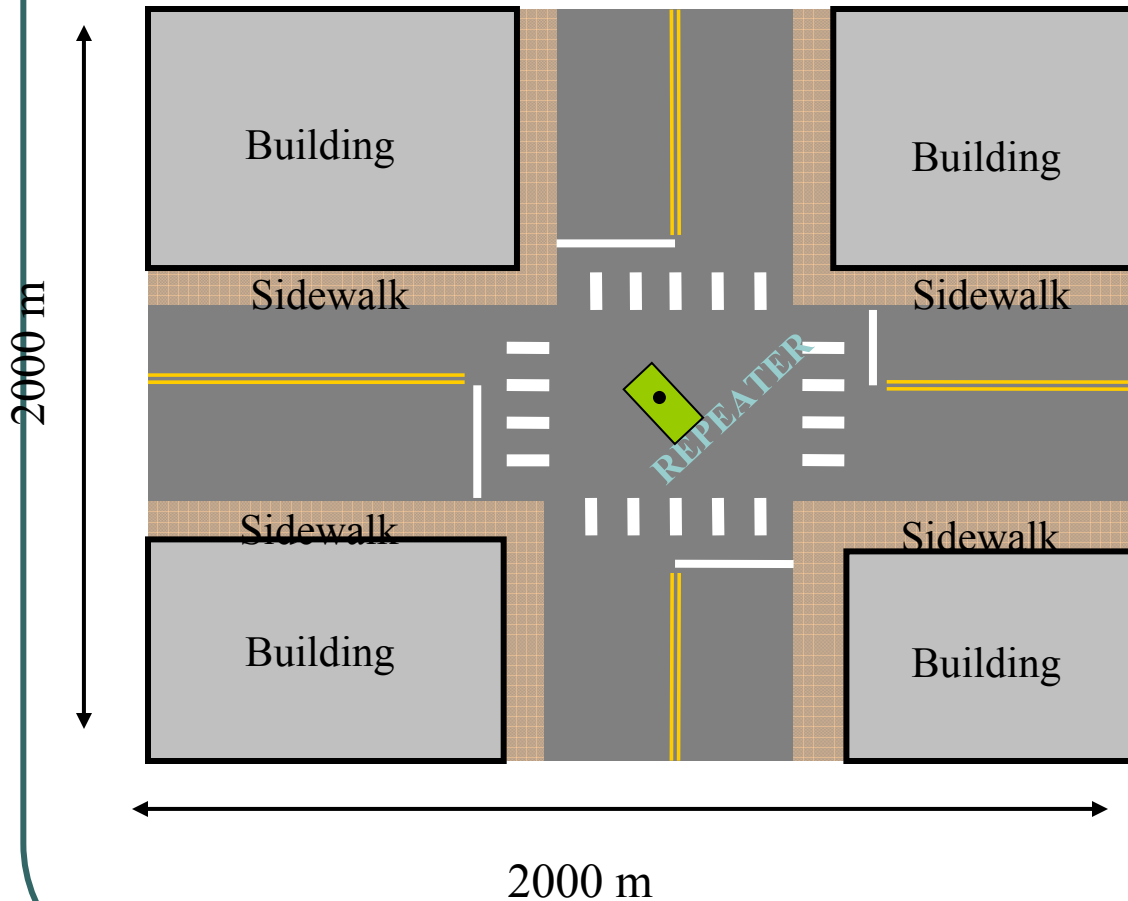


Physical Layer

- Physical layer specifications
 - Transmit power [10 dBm]
 - Receiver sensitivity [-82 dB]
- When there is a line-of-sight, the received power is mainly contributed by the direct path and the reflection. (Two Ray Model)
- When there is an obstruction, virtual source model is used. (RED PATH)

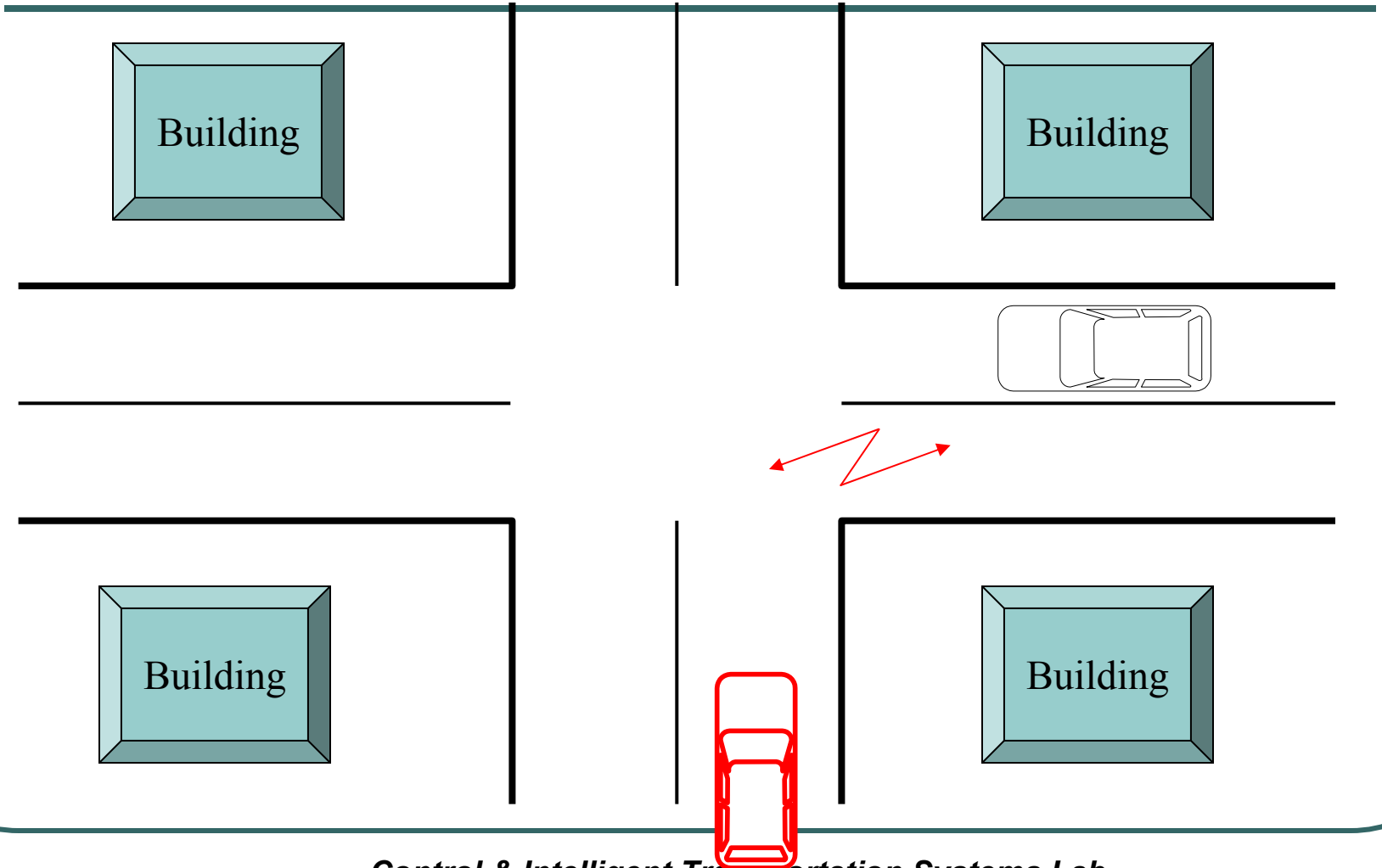


Simulation Environment



- 2 lanes in each road segment
- Vehicle Density = 50 vehicles per lane per km
- Packet size = 150 bytes

Intersection collision warning



Screenshot of intersection collision simulator

Simulation time

Wireless repeater

Building location

Truck

Receiver

Motorcycle

Transmitter

Intersection Type

- Traffic signal
- North – South
- Stop sign

Collision warning

Motorcycle

Bus

Car

Receiver

Last message

Critical messages

Last collision

Wireless Simulator

Time	Source (ID)	Receiver (ID)
25.451	35	37

Warning Message

Time	Source (ID)	Receiver (ID)	Level
24.714	30	33	3
24.779	32	31	3
24.818	31	30	1
24.877	31	32	3
25.241	32	35	3
25.321	33	32	3
25.453	35	32	3

Accidents! Vehicle 31 and Vehicle 30!!!



Demonstrating at ITS
World Congress,
Nagoya

More autonomous vehicles

- Automated Highway Systems
- Off-road vehicles

What role does V2V have to play?

Autonomous driving and the Demo-97 experience



Short distance information issues in off road vehicles

- Obstacle avoidance: **Larger set**
- Lane change: **No**
- Intersection collision avoidance: **No**
- Lane keeping: **On dirt road (no lane markers)**
- Convoying: **In the future**
- Stop-and-go in-city: **No**



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MICHELIN

OSHKOSH

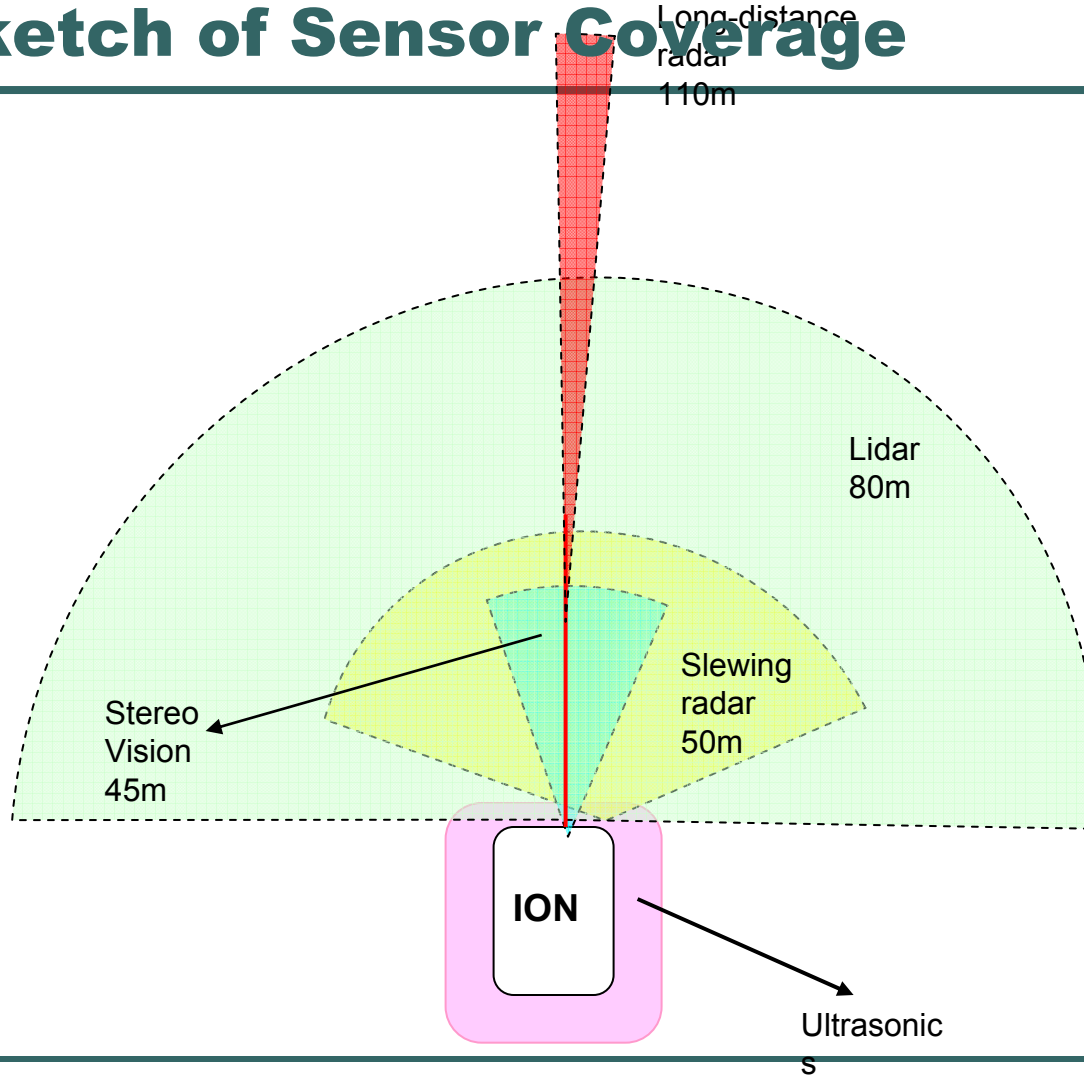
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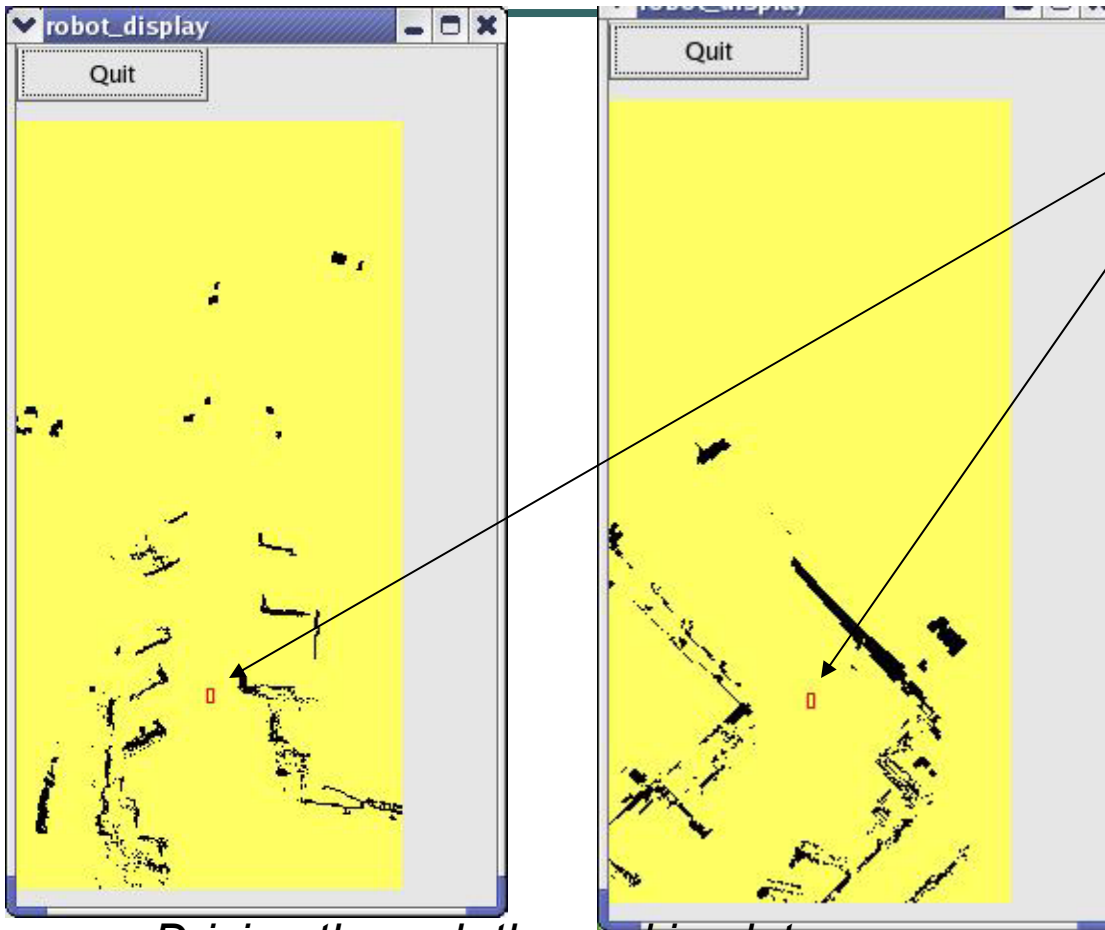
**Race day is
October 8, 2005.**



Sketch of Sensor Coverage



Sensor Fusion (Showing Lidar Only)



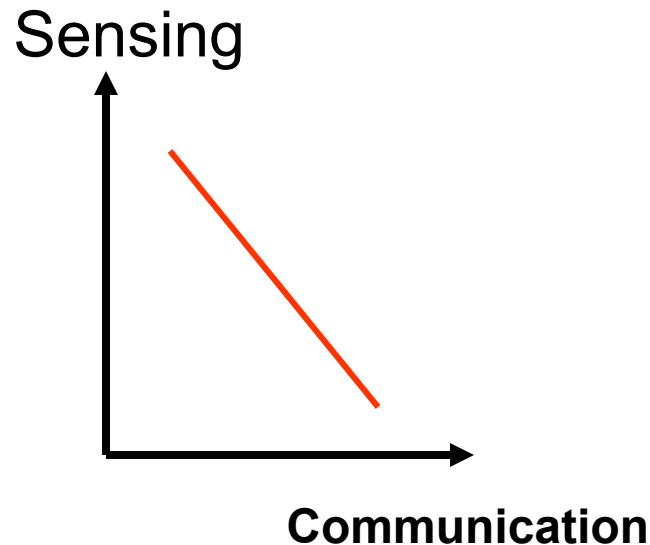
Driving through the parking lot

ION

The local grid map is 120 meters long and 40 meters wide. It moves with the vehicle. As more sensors become available the info will be fused on the map.

On the display shown, the vehicle is placed such that the map reveals 80 meters ahead and 40 meters behind.

The future?



- Autonomy requires extensive real-time information
- Both relative sensing and communication will be used
- Latency is important
- Guaranteed service is important