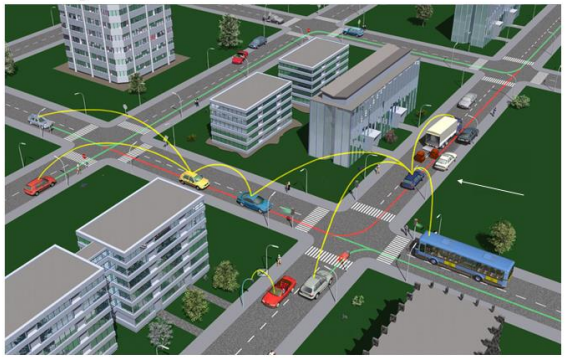
Introduction to Connected Vehicles (CVs)

Introduction to Connected Vehicles

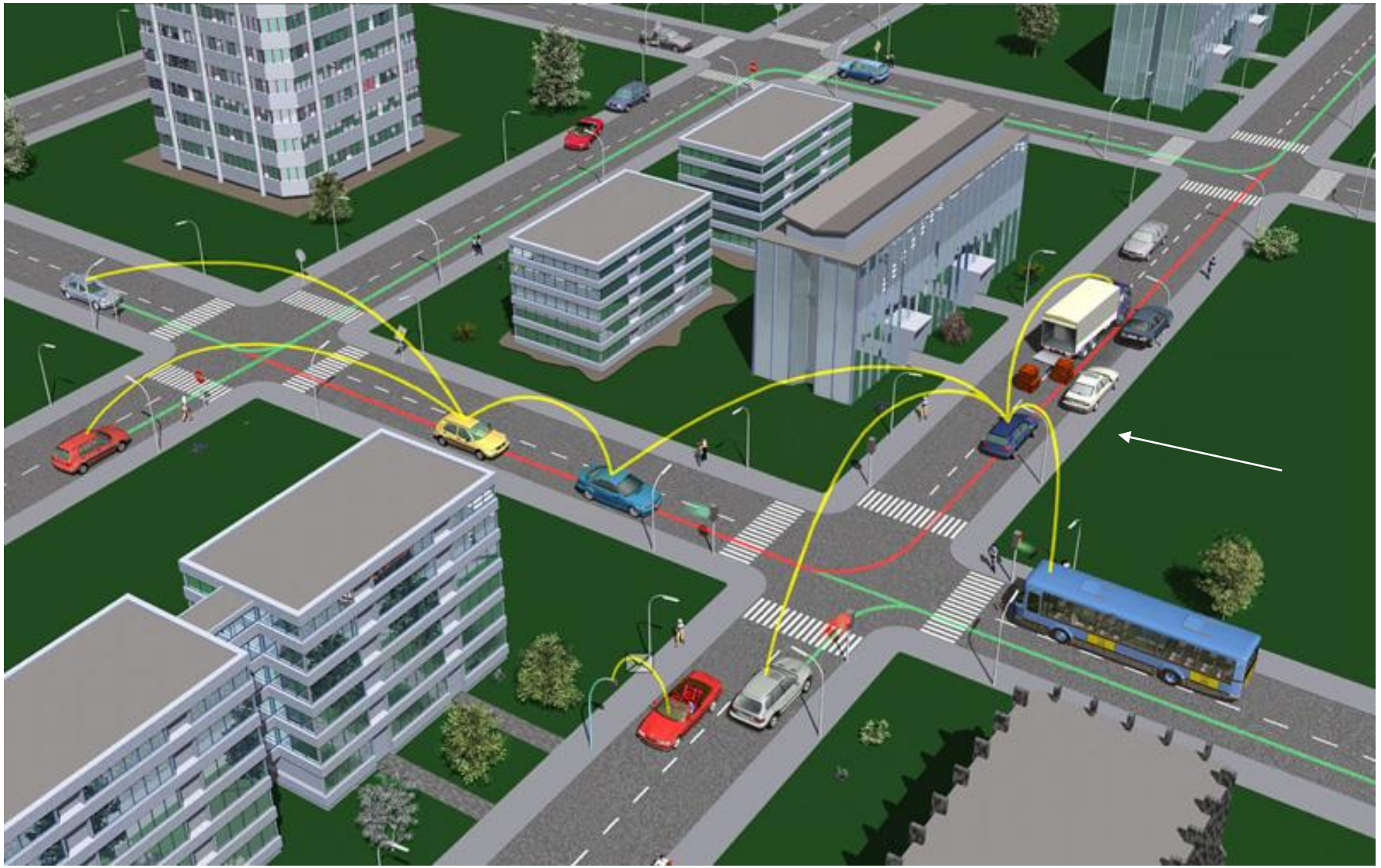
Roadways of the Future



Vehicular Communication

V2X: Global Perspective

Roadways of the Future



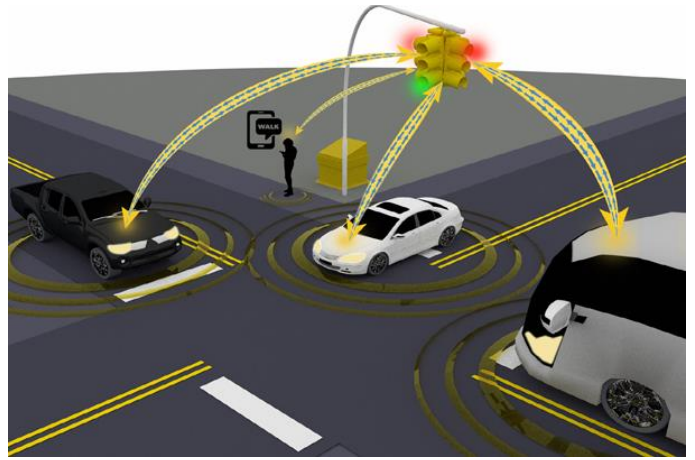
Connected Vehicles (CVs)

- Let vehicles "talk" to enhance proximity awareness
  - Can reduce $> 60\%$ of the deaths on the roads
    - 98% of accidents today are due to human errors ☹
  - Increase transportation system efficiency
    - Reduced travel time, less traffic, and less pollution
  - Comfort while driving, social inclusion (mobility for all), …
    - Autonomous, semi-autonomous, and non-autonomous cars
- Emerging technology with rapid growth
  - Projected market value by 2028: $12.8 billion
  - Volkswagen, BMW, Ford, Tesla, Nissan, Cadillac, Audi, etc.

Vehicular Communication

Types of CV Communication

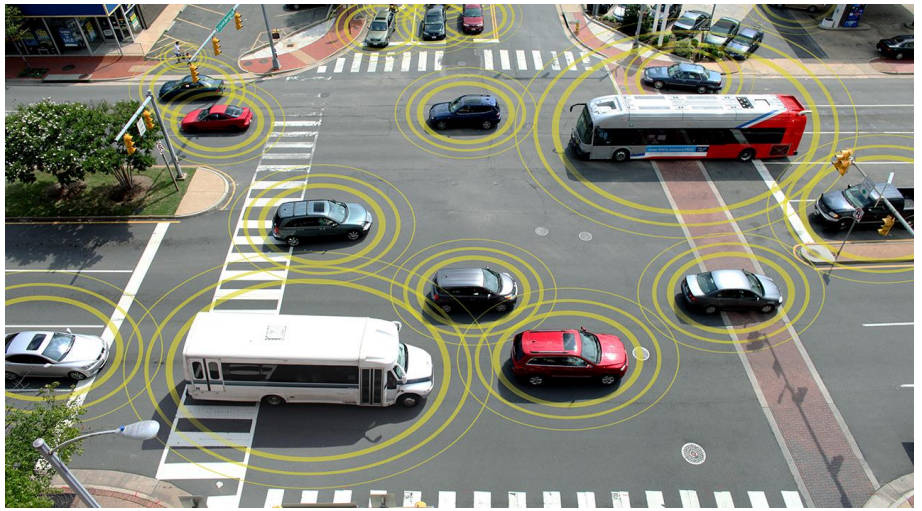
- Exploit wireless waves to talk
- To whom is the vehicle talking?
  - Vehicle-to-Vehicle (V2V)
  - Vehicle-to-Network (V2N)
  - Vehicle-to-Pedestrian (V2P)
  - Vehicle-to-Infrastructure (V2I)
  - Vehicle-to-[*insert your choice*] —> V2X
    - V2X = Vehicle-to-Everything



[Courtesy: Department of Transportation]

Vehicle-to-Vehicle (V2V)

- Vehicles "talk" to each other
  - Directly exchange wireless messages
- Coordinate with nearby vehicles
  - Movement, speed, intersections, …



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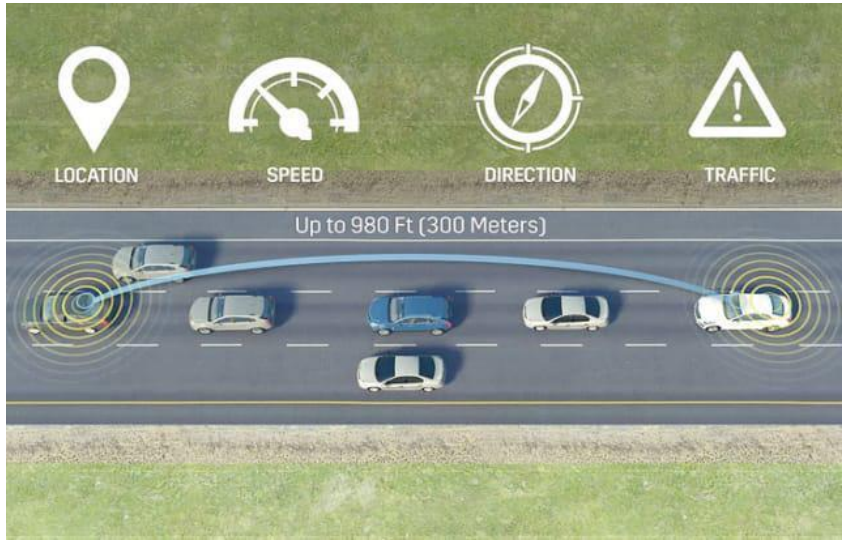

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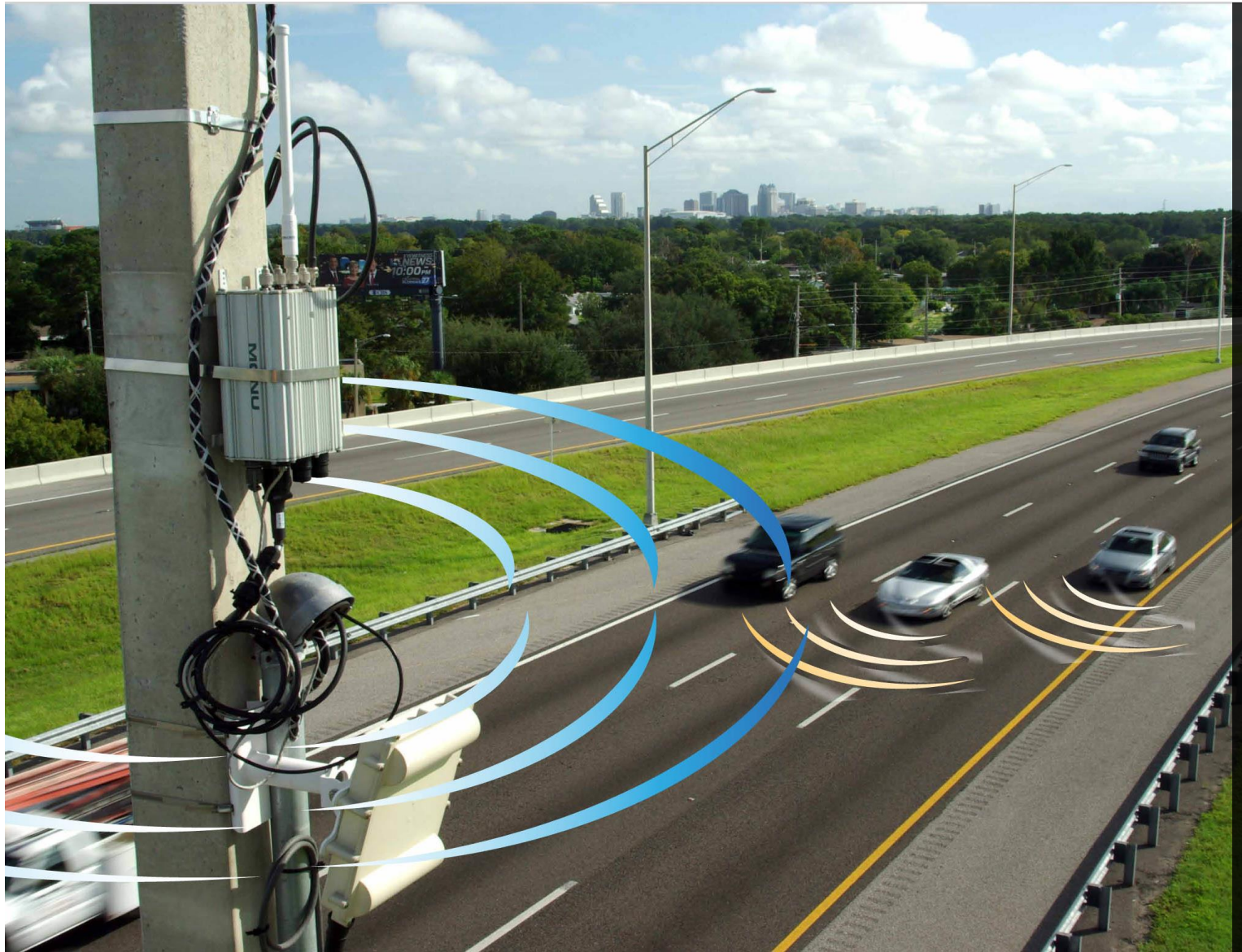
- Support non-line-of-sight (NLOS)
- Allow 360^0 coordination

Vehicle to Infrastructure (V2I)



Roadside Units (RSU)

- Devices installed along the roadway
- Capable of relaying V2X messages
- Can interface with traffic management systems like traffic light controllers

V2X: Global Perspective

Brief History of V2X in the U.S.

1996	OnStar® emergency assistance is the first form of vehicle connectivity
1999	FCC allocates 75 MHz of the 5.9 GHz band exclusively for V2V
2004	IEEE Task Group formed to investigate V2V based on 802.11 protocol
2010	First V2V protocol - Dedicated Short-Range Communication (DSRC) based on 802.11
2016	Cadillac CTS becomes first U.S. model to hit the roads with DSRC
2017	Second V2V protocol - Cellular Vehicle-to-Everything (C-V2X) based on LTE
2019	Ford announces C-V2X on all models beginning in 2022 Volkswagen announces DSRC on new Golf sedans Toyota cancels plans for DSRC on all models beginning 2021
2020	FCC cuts V2V spectrum by 50%, obsolesces DSRC in favor of C-V2X New C-V2X protocol standardized based on 5G technology
2022?	Next-generation V2X (NGV) – major upgrades to both DSRC and C-V2X expected

V2X Around the World

- Slow adoption rapidly accelerating since 2015
- 2015 – Toyota models sold in Japan with DSRC
- 2017 – Cadillac CTS sedans sold in U.S. (DSRC)
- 2019 – Ford announces C-V2X on all U.S. models from 2022
  – Volkswagen announces DSRC on new Golf sedans
- 2020 – China begins mass-producing vehicles with C-V2X
- 2021 – Nationwide C-V2X deployment begins in China

Trend is away from DSRC towards C-V2X (with exceptions)

Spectrum Allocation for V2X

- 5900 MHz bands are internationally common

Region	Frequency bands (MHz)
E.U.	5855 – 5925
U.S.	5895 – 5925
Japan	5850 – 5925
China	5905 – 5925

- Additional bands are now under active consideration
  - IEEE 802.11bd is designed for 60 GHz
  - NR-V2X (5G) supports 24.25 – 52.6 GHz