MATLAB EXPO 2017

MAC + PHY Modeling & Multilayer Simulation of DSRC V2V Network

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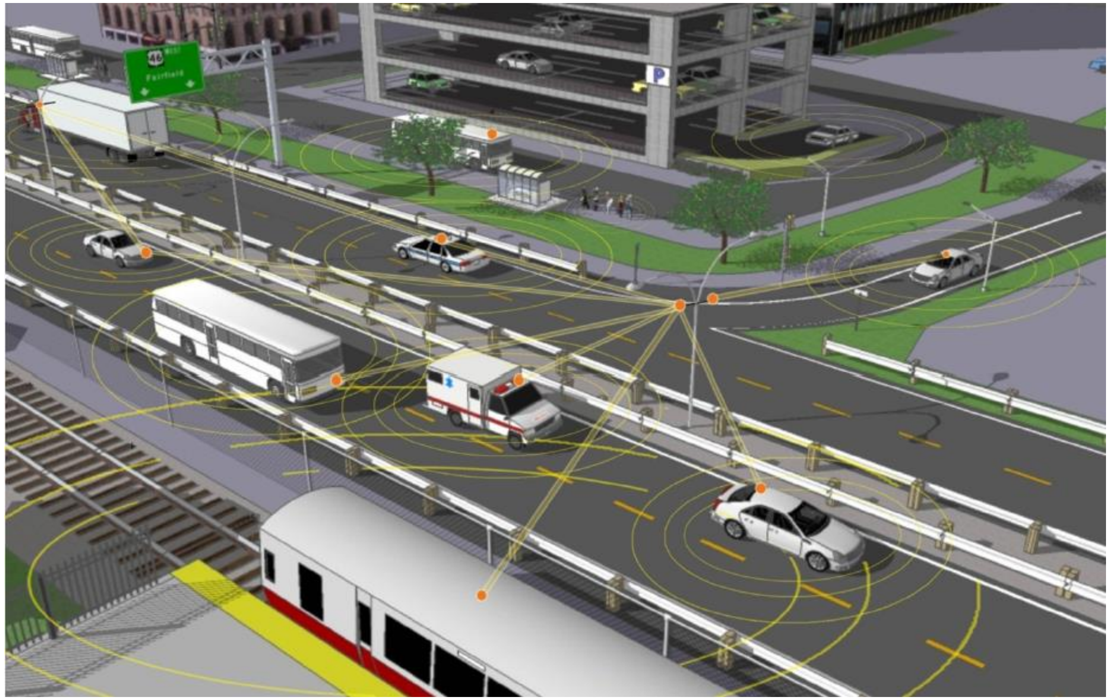
Vehicular Communications

- Vehicle-to-Vehicle (V2V)
- Vehicle-to-Infrastructure (V2I)
- Vehicle-to-Pedestrian (V2P)
- Vehicle-to-Network (V2N)

} V2X



➢ Continuous, high-speed, and authenticable safety data exchange among moving vehicles (V2V) and between vehicles and roadway infrastructure (V2I), pedestrians (V2P) and cellular network (V2N)

Motivations for V2X

- Safety
  - 33,000 death in highway accidents (US DOT, 2012)
  - 5.1 million crashes (US DOT, 2012)
  - Leading cause of death for people of age 11-27
- Mobility & Productivity
  - 5.5 billion hours of traffic delay (per year)
  - 121 billion USD cost of urban congestion (per year)
- Environment
  - 2.9 billion gallons of waste in fossil fuel (per year)
  - 56 billion lbs. of additional emitted CO_2

Impact of V2X technology

- US DOT NHTSA: If V2X technologies alone are widely deployed, they have the potential to address 81 percent of light-vehicle crashes

- V2X based on cooperative communications

- Extends the safety features offered by Advanced Driver Assistance Systems (ADAS) technologies
  - RADAR
  - LiDAR
  - Video processing

V2X Safety Applications

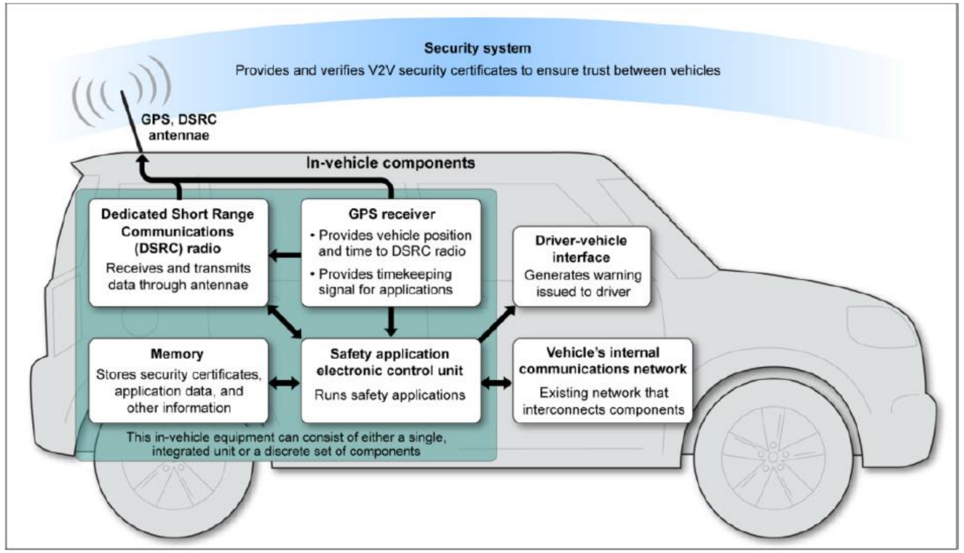
V2I Safety	V2V Crash Avoidance Safety
• Red Light Violation Warning • Curve Speed Warning • Stop Sign Gap Assist • Spot Weather Impact Warning • Reduced Speed/ Work Zone Warning • Pedestrian in Signalized Crosswalk Warning (Transit)	• Emergency Electronic Brake Lights (EEBL) • Forward Collision Warning (FCW) • Intersection Movement Assist (IMA) • Left Turn Assist (LTA) • Blind Spot/ Lane Change Warning (BSW/LCW) • Do Not Pass Warning (DNPW) • Vehicle Turning Right in Front of Bus Warning (Transit)

Proposed V2X Technologies

1. Dedicated Short Range Communications (DSRC)

2. Cellular Vehicle-to-Any-Device communications (C-V2X)

- Operating at 5.9 Gigahertz (GHz) band
- Strict performance requirements
  - Latency: Less-than-100-ms delay
  - Range: Up to 300 meters
  - Supported speeds: Typical highway velocities



Sources: Crash Avoidance Metrics Partnership and GAO.

- Using Basic Safety Messages (BSM) data exchange

Basic safety messages (BSM) & algorithm development

Data Frame (DF)	Data Element (DE)
Position (DF)	
	Latitude*
	Elevation*
	Longitude*
	Positional accuracy*
Motion (DF)	
	Transmission state*
	Speed
	Steering wheel angle
	Heading*
	Longitudinal acceleration*
	Vertical acceleration
	Lateral acceleration
	Yaw rate*
	Brake applied status
	Traction control state
	Stability control status
	Auxiliary brake status
	Brake status not available
	Antilock brake status
	Brake boost applied
Vehicle size (DF)	
	Vehicle width
	Vehicle length

Position information

Velocity information

Acceleration information

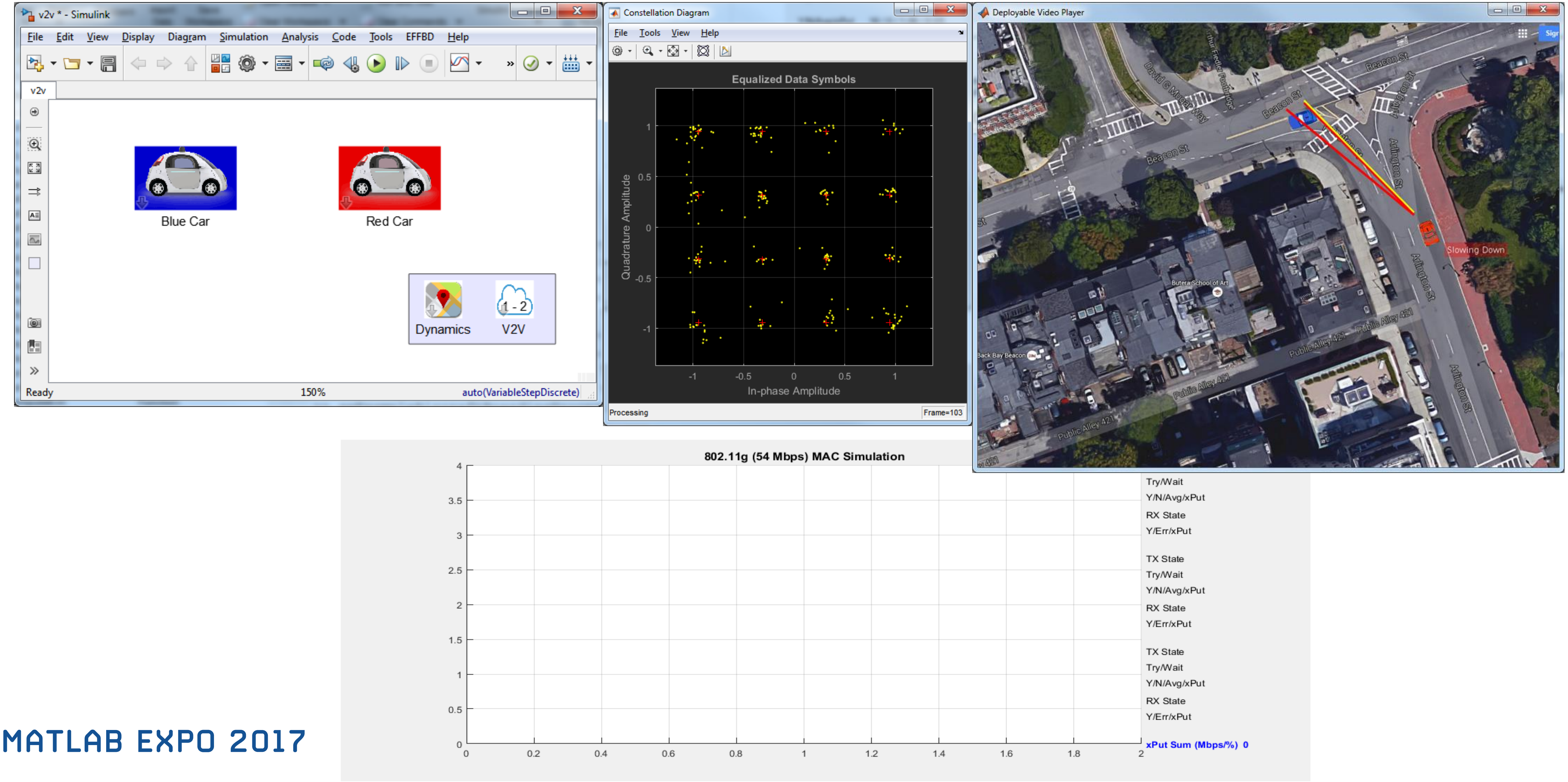
Size information

What you will learn today

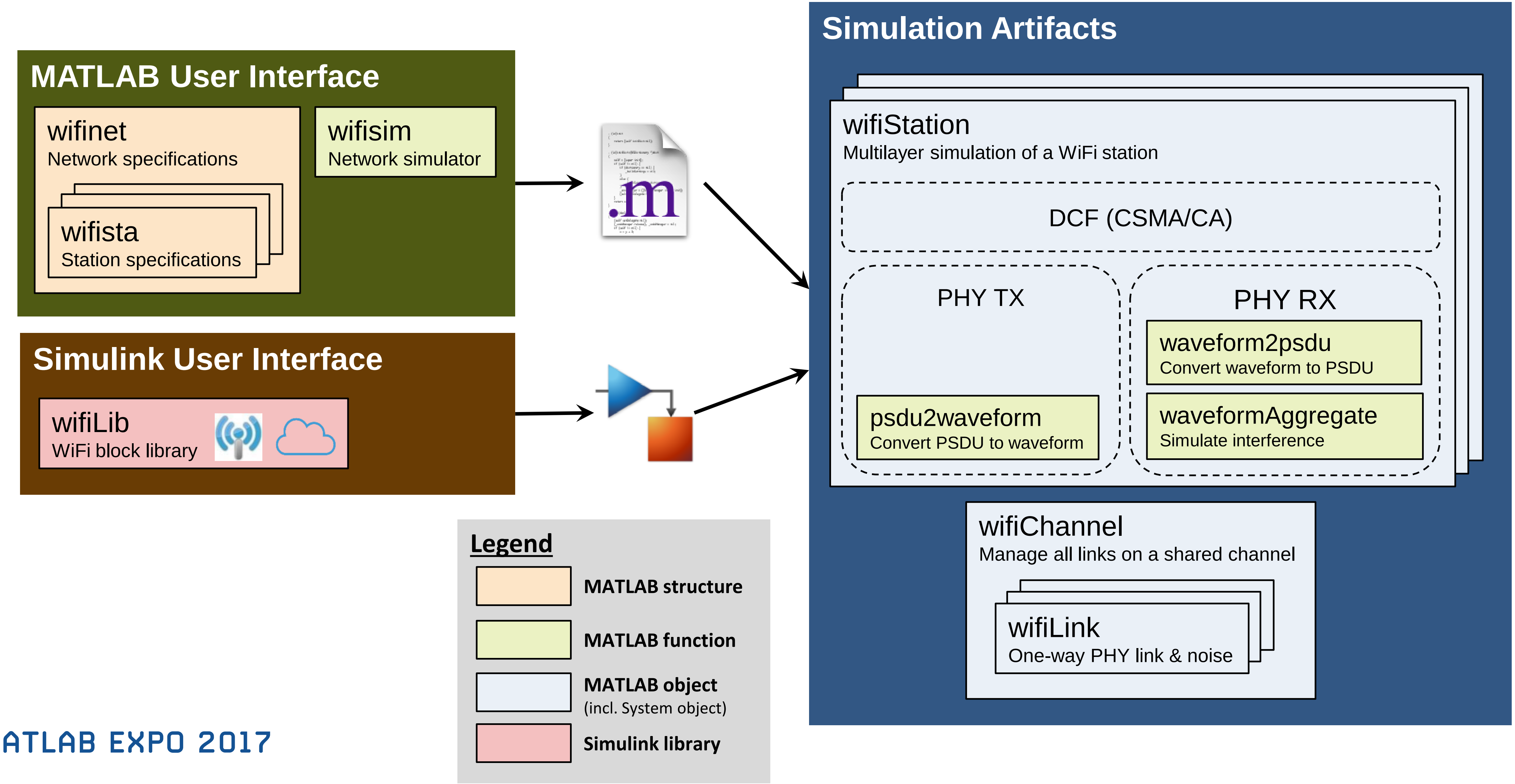
How to model, simulate, visualize V2X safety applications:

1. Visualize and model traffic scene and vehicles in motion
2. Apply equations of motion to handle vehicular maneuvers, collision prediction, collision avoidance and after-collision trajectory algorithms
3. Simulate IEEE 802.11p physical layer of DSRC standard for V2V communications
4. Simulate IEEE MAC layer of DSCR standard at the same time as the PHY

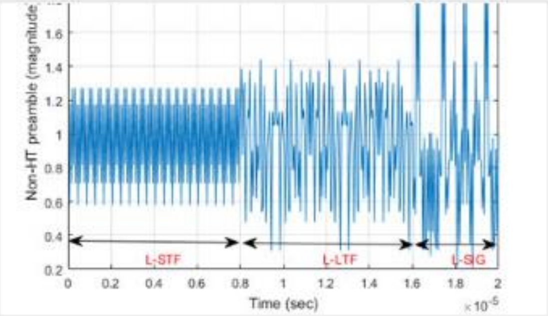
Example: 802.11p V2V Safety Scenario Simulation



Implementation

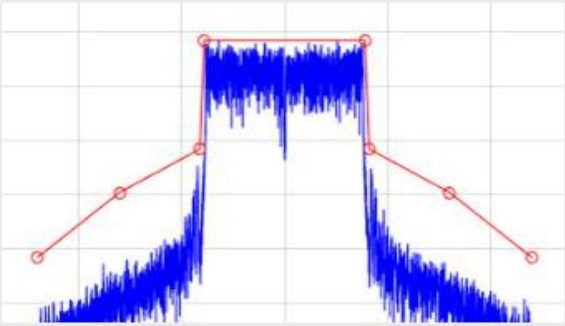


802.11 PHY design made easy with WLAN System Toolbox



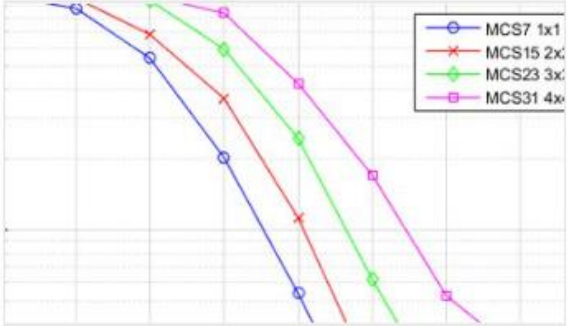
Signal Generation

Generate a variety of standard-compliant waveforms that you can use as golden references.



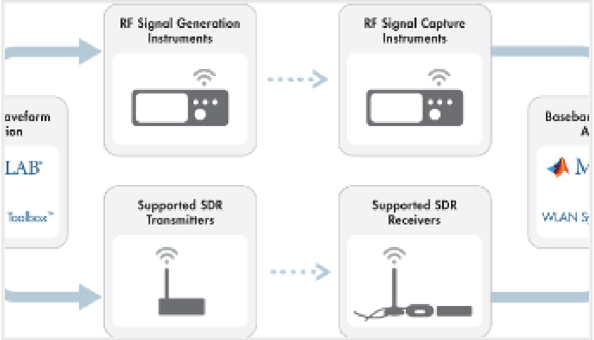
Signal Measurement

Verify that transmitted or received signals meet performance specifications, and analyze system response to the noise and interference.



Link-Level Simulation and Throughput Analysis

Perform link-level simulations of IEEE 802.11 standards.



Radio Connectivity

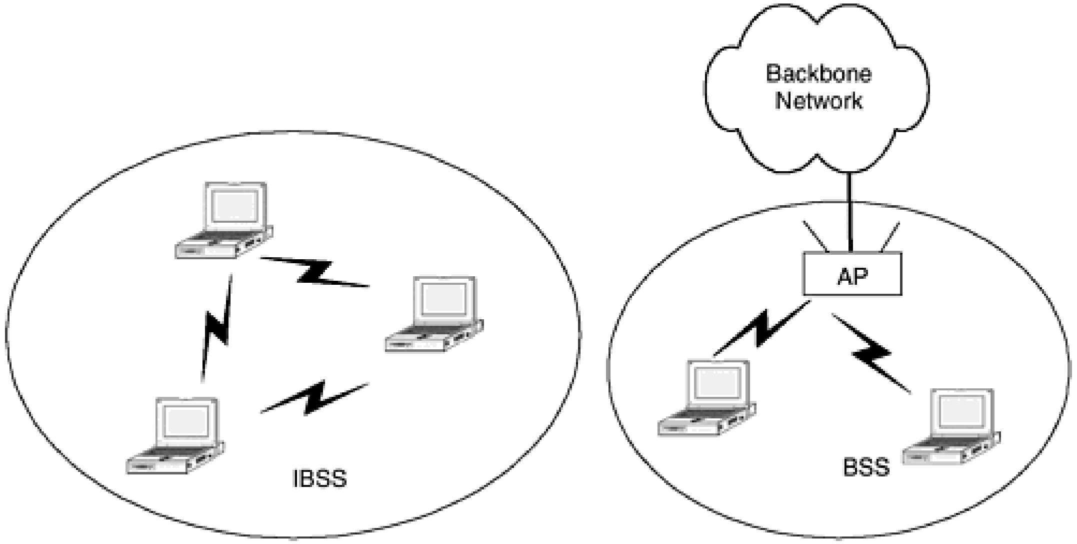
Transmit waveforms over the air using RF signal generators or supported software-defined radio (SDR) devices.

802.11 MAC and CSMA/CA
(Carrier Sense Multiple Access with Collision Avoidance)

- Media Access Control (MAC) – a set of rules that coordinate stations to share common bandwidth efficiently

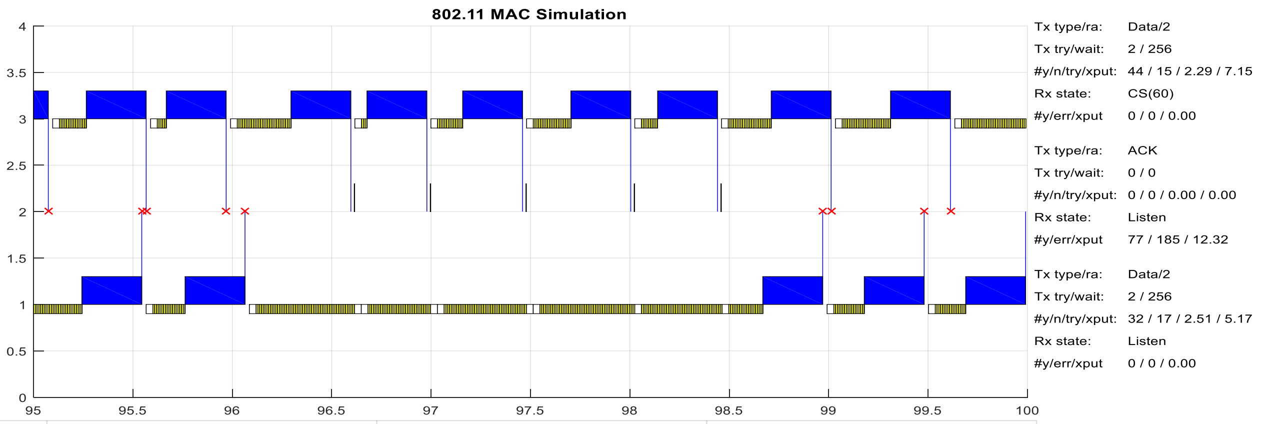
- 802.11 uses CSMA/CA method for both
  - Ad-hoc (or IBSS) mode, and
  - Infrastructure mode

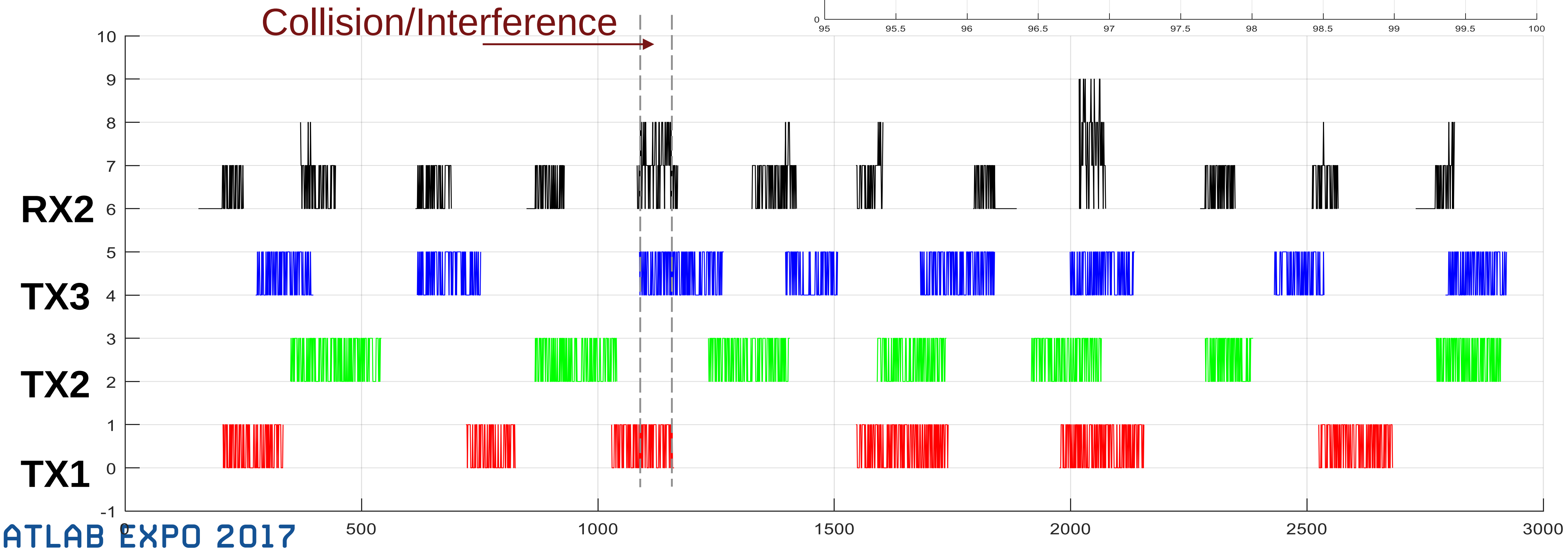
- CSMA/CA includes 2 mechanisms
  - Basic access
  - RTS/CTS (Request To Send/Clear To Send)



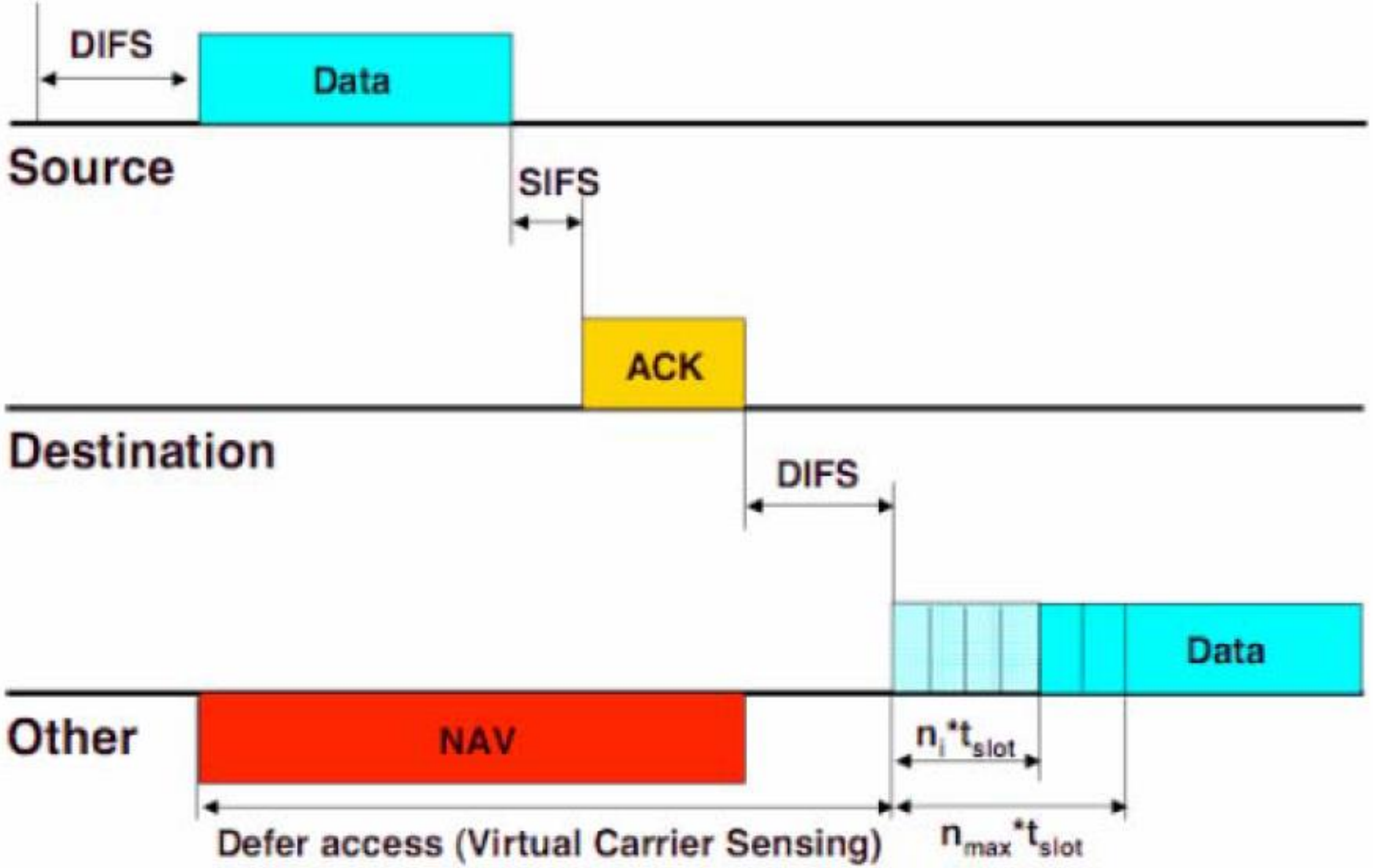
Simulate Interference of Multiple Bursts of Waveforms

- Receiver “hear” time-shifted aggregation of waveforms
- An illustrative example





CSMA/CA Basic Access



Source station states

1. Carrier sense (DIFS)
2. Random back-off
3. Transmit data
4. Turn-around (SIFS)
5. Wait/receive ACK

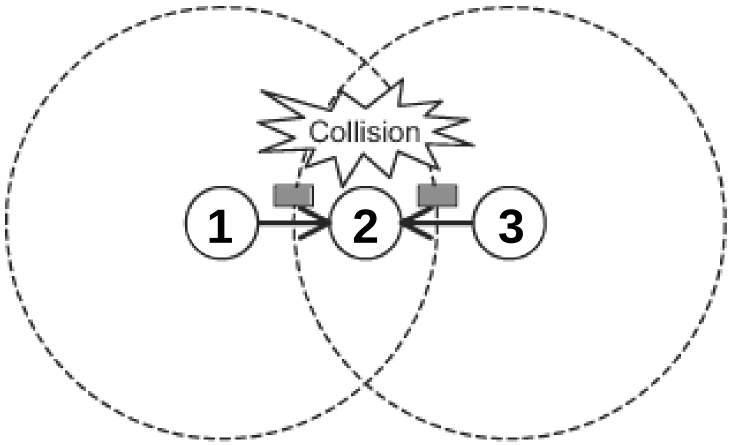
Other station

Virtual carrier sensing

Listen/read “duration” field of MAC headers, set NAV (Network Allocation Vector) counter as indicator of channel “busy”

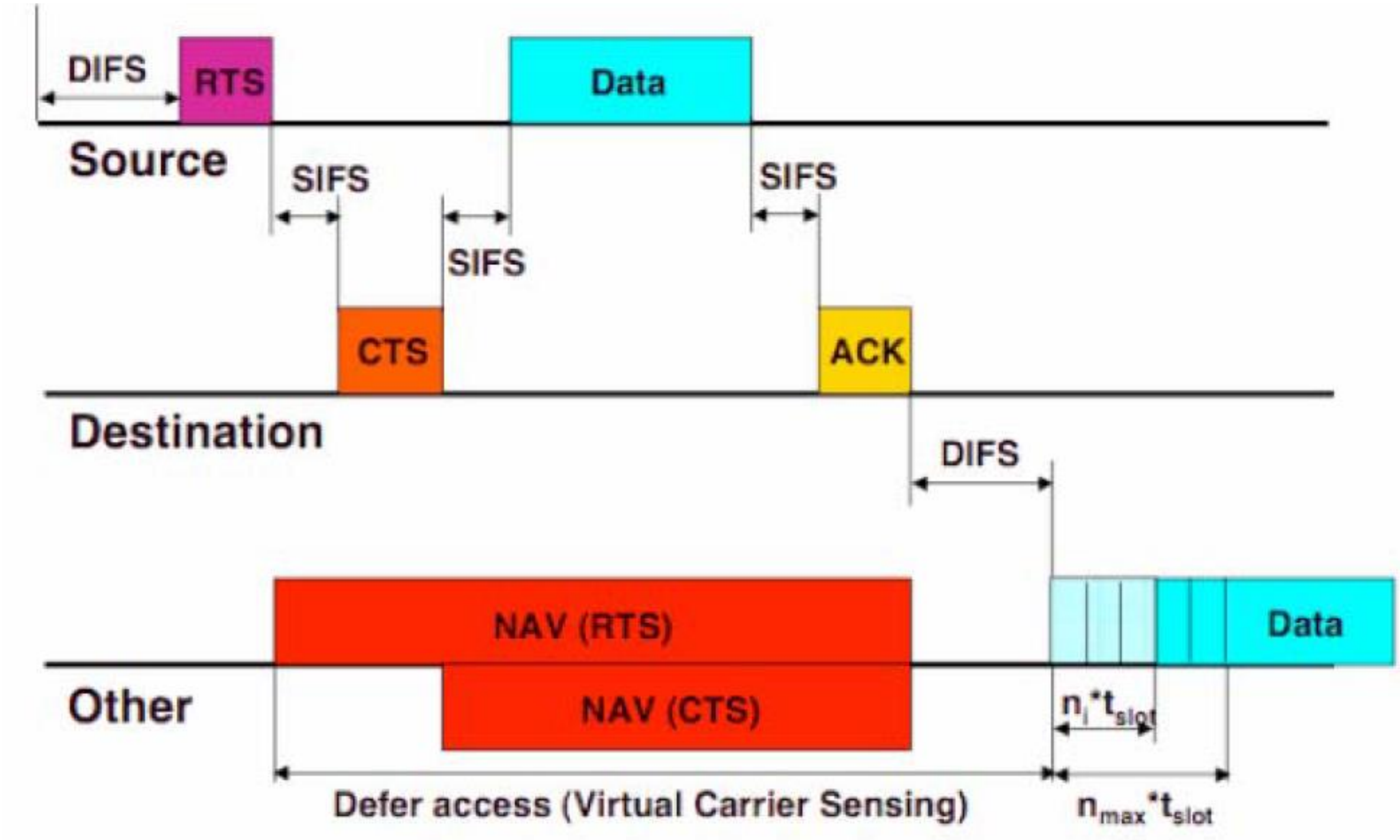
How 802.11 RTS/CTS Resolve Hidden Terminal Problem

- CSMA basic access cannot avoid the collisions due to “hidden terminal problem”
  - 1 is sending data to 2
  - 3 is out of range of 1, therefore believes channel free
  - 3 sends data to 2 and causes collision



- RTS/CTS can help
  - 1 sends RTS (Request To Send) to 2
  - 2 responds with CTS (Clear To Send)
  - CTS heard by both 1 and 3
  - 1 starts to send data
  - 3 detects CTS is for others, and set NAV

CSMA/CA with RTS/CTS

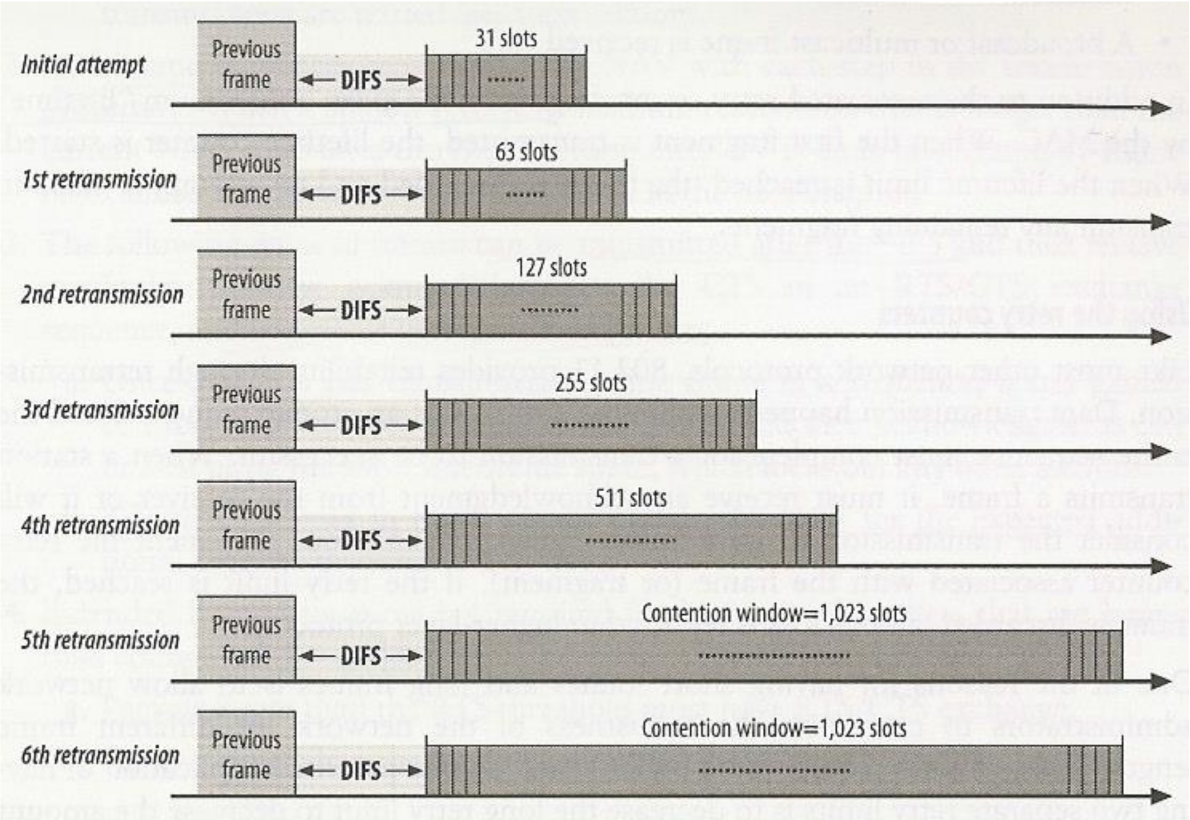


Source station states

1. Carrier sensing (DIFS)
2. Random back-off
3. RTS
4. Turn-around (SIFS)
5. Wait/receive CTS
6. Turn-around (SIFS)
7. Transmit data
8. Turn-around (SIFS)
9. Wait/receive ACK

NAV of RTS/CTS covers entire data transmission

Re-transmission

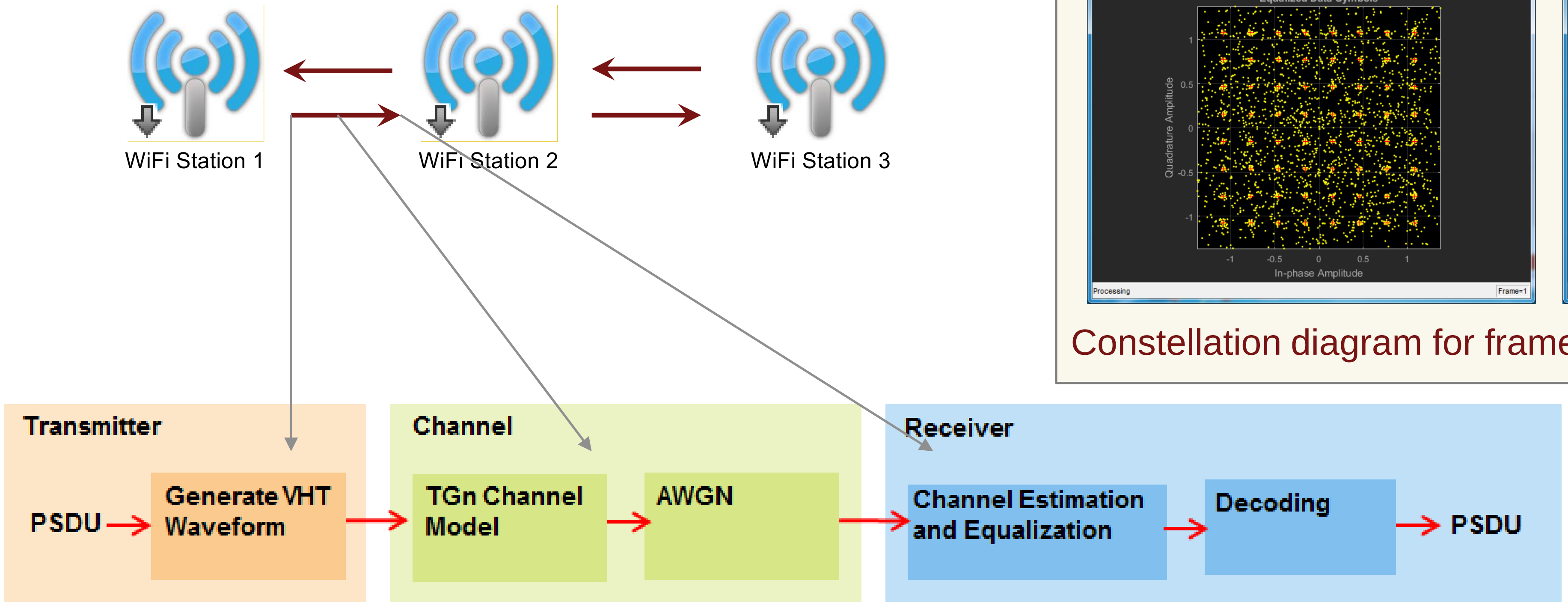


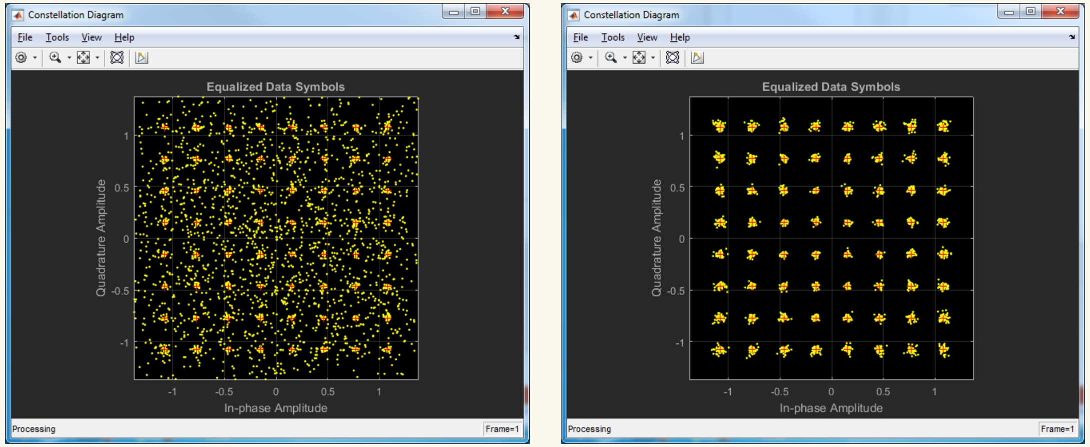
- Increase retry counter
- Doubles Contention Window (CW) up to CW_max
- Backoff counter = random number between [0, CW]
- Initial attempt: CW = CW_min
- Drop the frame when:

  Retry counter > Retry_max

Example re-transmission configuration
CW_min = 31, CW_max = 1023, Retry_max = 6

Multilayer Simulation Enable MAC/PHY Co-Design



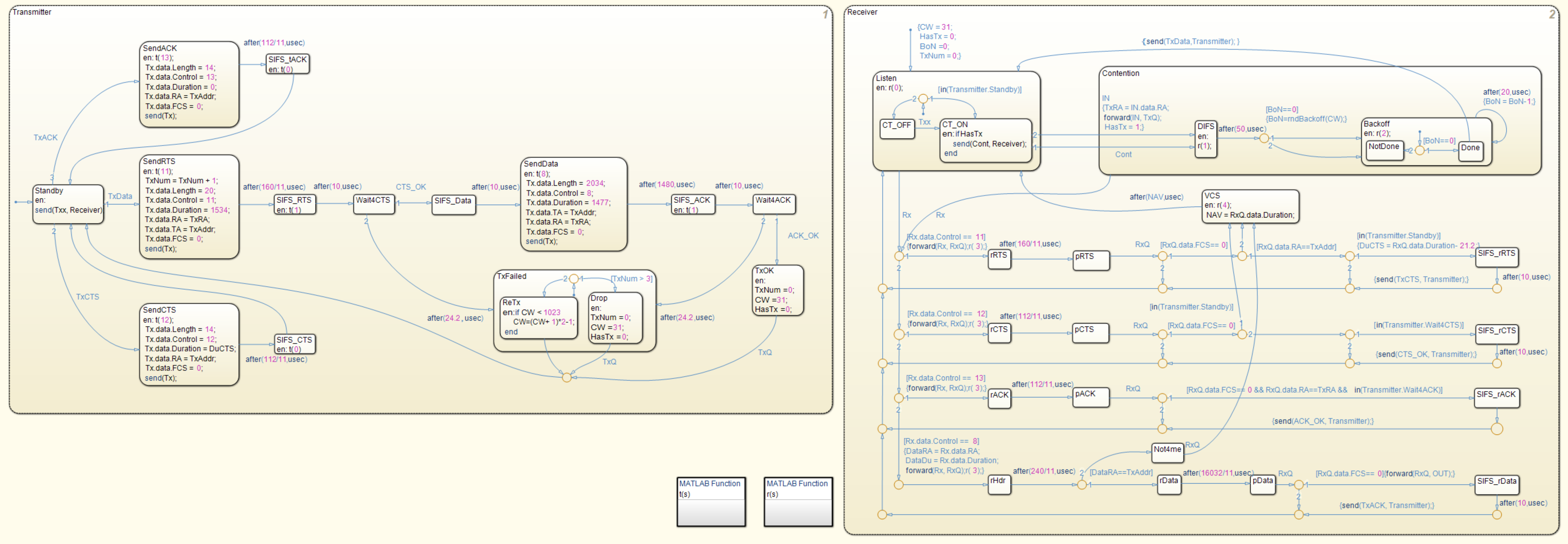


Constellation diagram for frames with and without collisions

- PHY simulation of creation, transmission, interference, reception and recover of a 802.11 VHT frame
- MAC simulation of multiple, independent stations with self-managed DCFs
- Support both MATLAB command-line and Simulink graphical modeling/simulation

DEMONSTRATION

Alternative Approach to Model/Simulate MAC Behaviors



Summary - MATLAB and Simulink provide:

- Framework for multilayer, multi-nodes network simulation
  - Simulate interference of multiple, independent bursts of waveforms on a shared channel
  - Help network design, diagnose, analysis, and performance evaluation

- Plug-in MAC and PHY components of different types
  - System object (MATLAB) based or Stateflow-based MAC
  - Any PHY waveform generator (802.11, LTE, …)

- Visualization tools to build meaningful scenarios

- Supports code generation as a next step for implementation