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# Coexistence of DSRC and Wi-Fi

## Impact on the Performance of Vehicular Safety Applications

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# Dedicated Short Range Communications (DSRC)

Vehicular Adhoc Networks (VANETs) are becoming increasingly important for road safety.

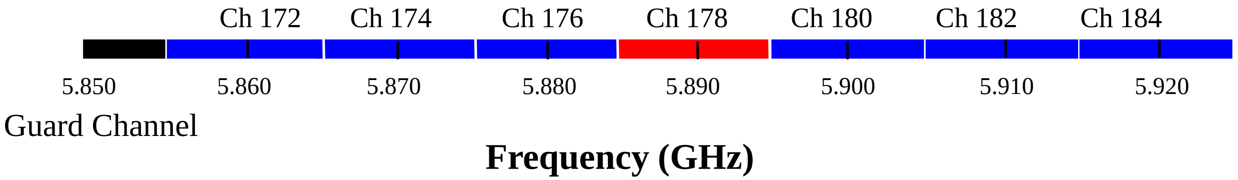
In 1999, FCC allocated 75 MHz of spectrum in the 5.9 GHz band for V2V and V2I communications.

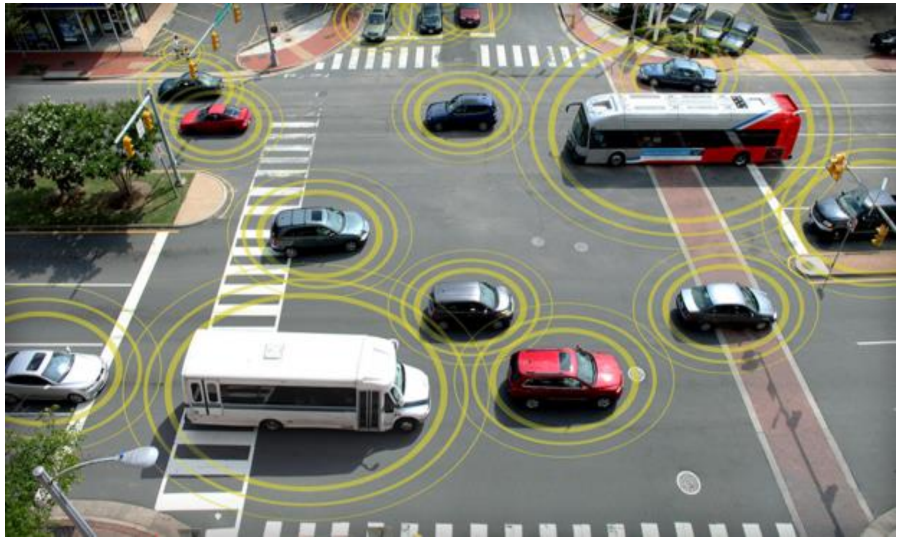
The proposed vehicular communication technology is the Dedicated Short Range Communications (DSRC).

PHY and MAC details in the IEEE 802.11p standard

The spectrum band 5850 – 5925 MHz band is reserved for DSRC

- Seven channels of 10 MHz each



http://www.extremetech.com/extreme/176093-v2v-what-are-vehicle-to-vehicle-communications-and-how-does-it-work

# The Coexistence Problem!

Despite its importance, there have not been widespread DSRC deployments

- Spectrum band under-utilized

In 2013, FCC issued a proposal to open up additional spectrum in the 5 GHz band for unlicensed operations (particularly Wi-Fi)

- Specifically, 5350 – 5470 MHz and 5850 – 5925 MHz bands
- The latter band completely overlaps with the band reserved for DSRC applications

Spectrum sharing scenario

- DSRC will remain primary users
- Wi-Fi (and others) to be secondary users

# Related Work

DSRC Coexistence *Tiger Team* Proposals

- Proposal 1:
  - Detect 10 MHz preambles at Wi-Fi
  - Back-off for 10 seconds when DSRC activity is detected.
- Proposal 2:
  - Move safety critical applications to upper 30 MHz (non-shared)
  - The lower 40 MHz to be shared with Wi-Fi.

DFS like approach – not practical

Requires re-channelization of DSRC (primary) systems

Two key Wi-Fi parameters that can facilitate DSRC – Wi-Fi coexistence [1, 2].

- Sensing range
- Inter-frame Spacing (IFS)

[1] J. LANSFORD ET AL., "COEXISTENCE OF UNLICENSED DEVICES WITH DSRC SYSTEMS IN THE 5.9 GHZ ITS BAND," IN IEEE VNC, 2013.
[2] Y. PARK AND H. KIM, "ON THE COEXISTENCE OF IEEE 802.11 AC AND WAVE IN THE 5.9 GHZ BAND," IEEE COMM. MAG., VOL. 52, ISSUE 6, 2014.

# DSRC Primer

Two types of safety critical messages

1. Event-driven messages
   - Transmitted when a hazardous event occurs

2. Basic safety messages (BSM)
   - Broadcasted periodically (default 100 milliseconds)
   - Contains sender's position, speed, acceleration etc.

**We analyze the impact of Wi-Fi transmissions on BSMs**

**DSRC specific 802.11 features**

- No ACK transmissions (on CCH)
- Fixed Contention Window
- Packet Expiration

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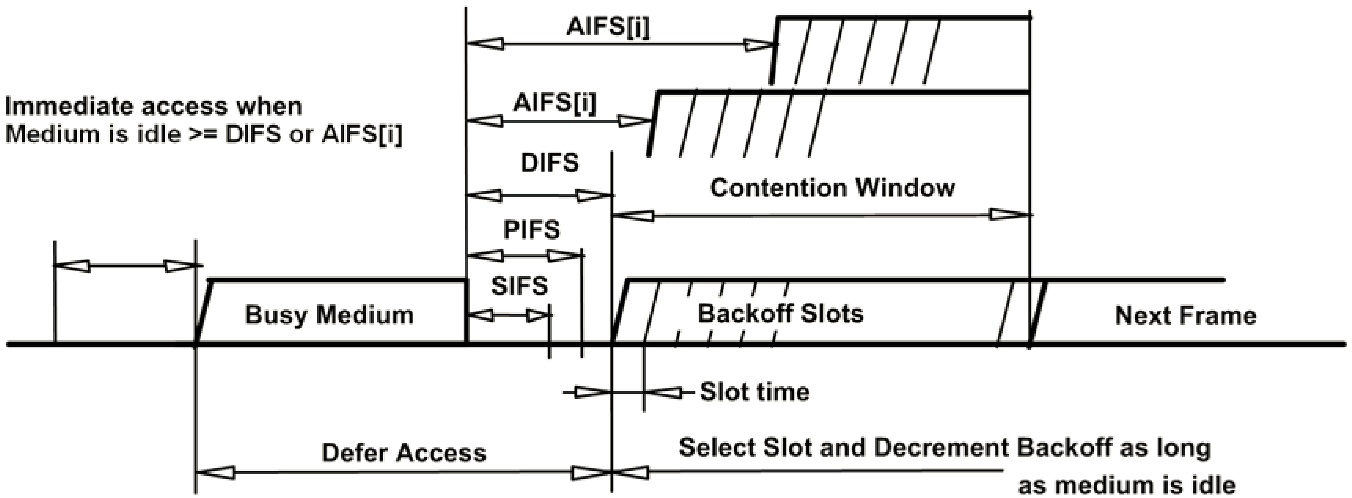
# Who will transmit first?




Wi-Fi DIFS = 23 microseconds

DSRC PIFS = 45 microseconds

**When DSRC and Wi-Fi devices are in close proximity, Wi-Fi device has higher priority for Channel Access**

# System Model

We direct our focus on a specific transmitter (Tx) – receiver (Rx) pair.

All DSRC nodes have,

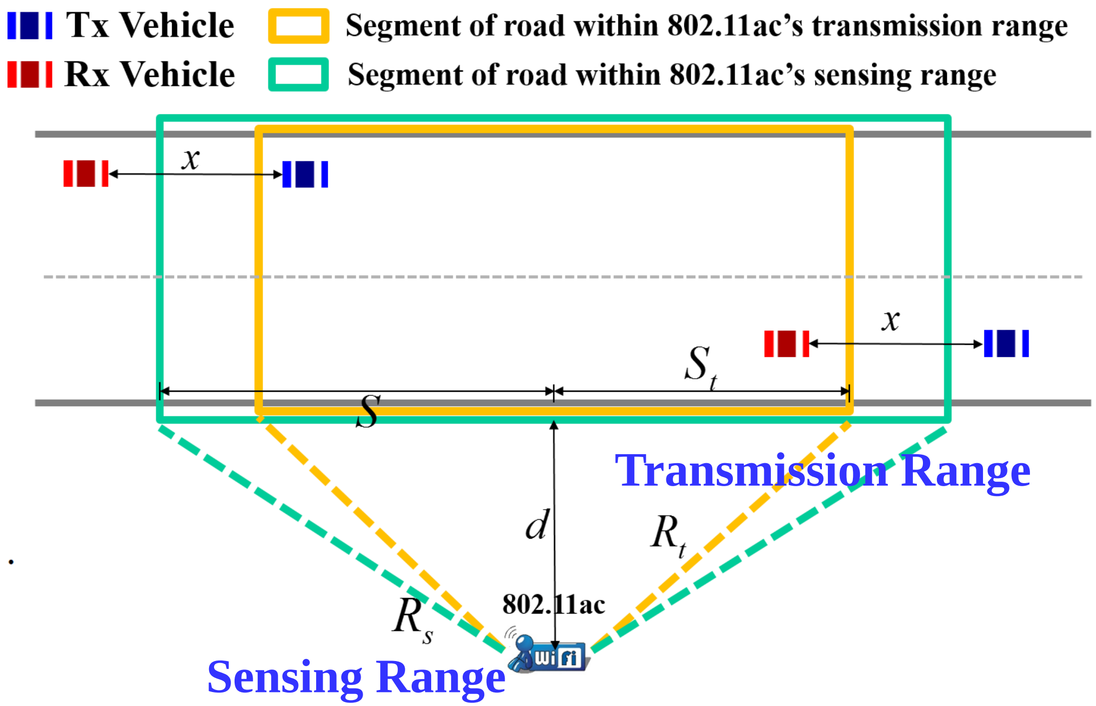
- transmission range = sensing range = R.

Wi-Fi node has,

- transmission range = $R_t$ = R.
- Sensing range = $R_s$

One dimensional model $P(\text{i vehicles in length l}) = \frac{(\lambda l)^i e^{-\lambda l}}{i!}.$

Vehicle density – Poisson distribution

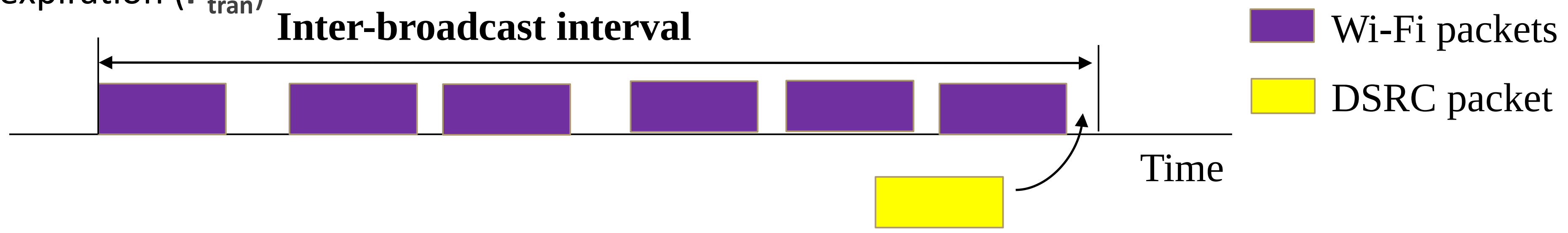


# Performance Analysis

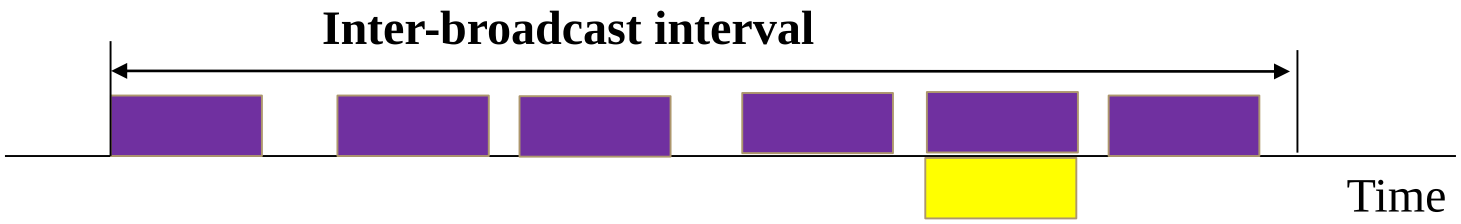
DSRC Performance Metric – Packet Delivery Ratio (PDR)

Packet loss can be attributed to one of three factors,

- Packet expiration ($P_{tran}$)




- Concurrent transmissions ($P_C$)




$$\text{PDR} = P_{\text{tran}} P_c P_H \, .$$

- Hidden Nodes ($P_H$)

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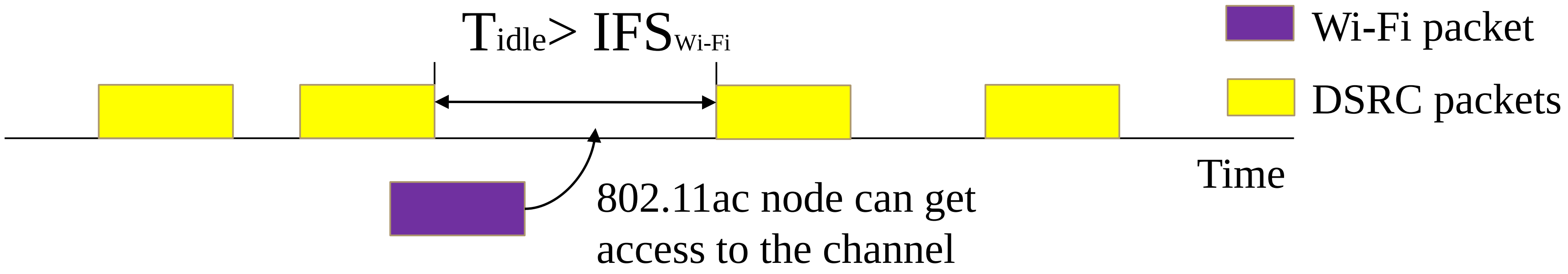
# Priority Reversal

Priority Reversal occurs when a Wi-Fi node gains access to the channel when DSRC nodes still have a packet to transmit.

Undesired behavior

When can Priority Reversal occur?



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# Computation of Probabilities

The probabilities have a non-tractable closed-form expression.

We use Monte-Carlo sampling to determine $P_{trans}$ and $P_c$.

$P_H$ is the computed using [3] as,

$$P_H = e^{-\frac{2 P_{\text{tran}} \lambda x T_1}{T_c}}.$$

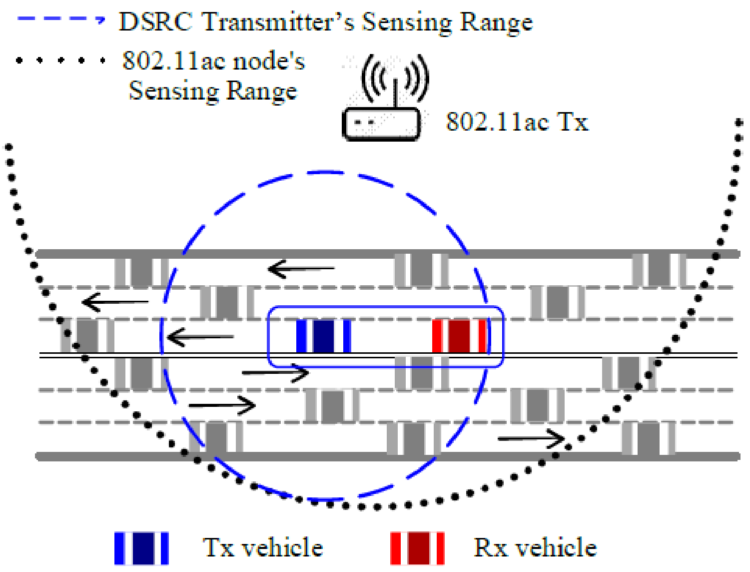
where, $T_c$ is the inter-broadcast interval,

$T_1$ is the time required to transmit DSRC headers and data.

[3] X. MA, J. ZHANG, AND T. WU, "RELIABILITY ANALYSIS OF ONE-HOP SAFETYCRITICAL BROADCAST SERVICES IN VANETS," VEHICULAR TECHNOLOGY, IEEE TRANSACTIONS ON, VOL. 60, NO. 8, PP. 3933–3946, 2011.

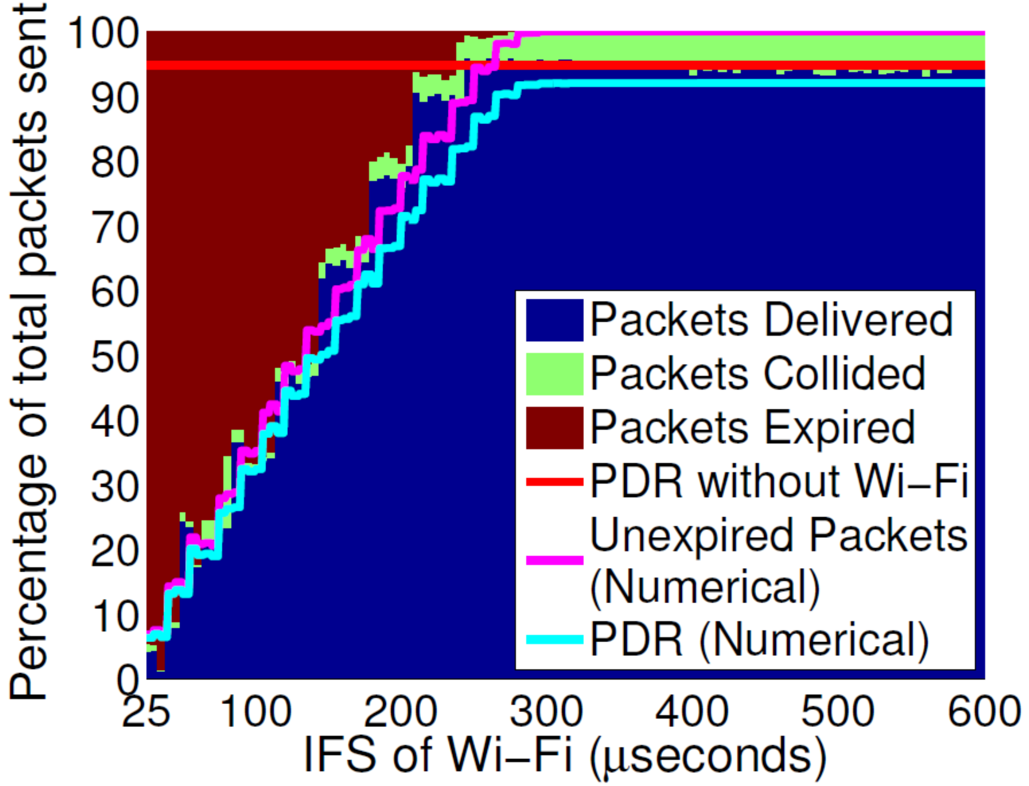
# Simulation Results

Simulations carried out using ns-3



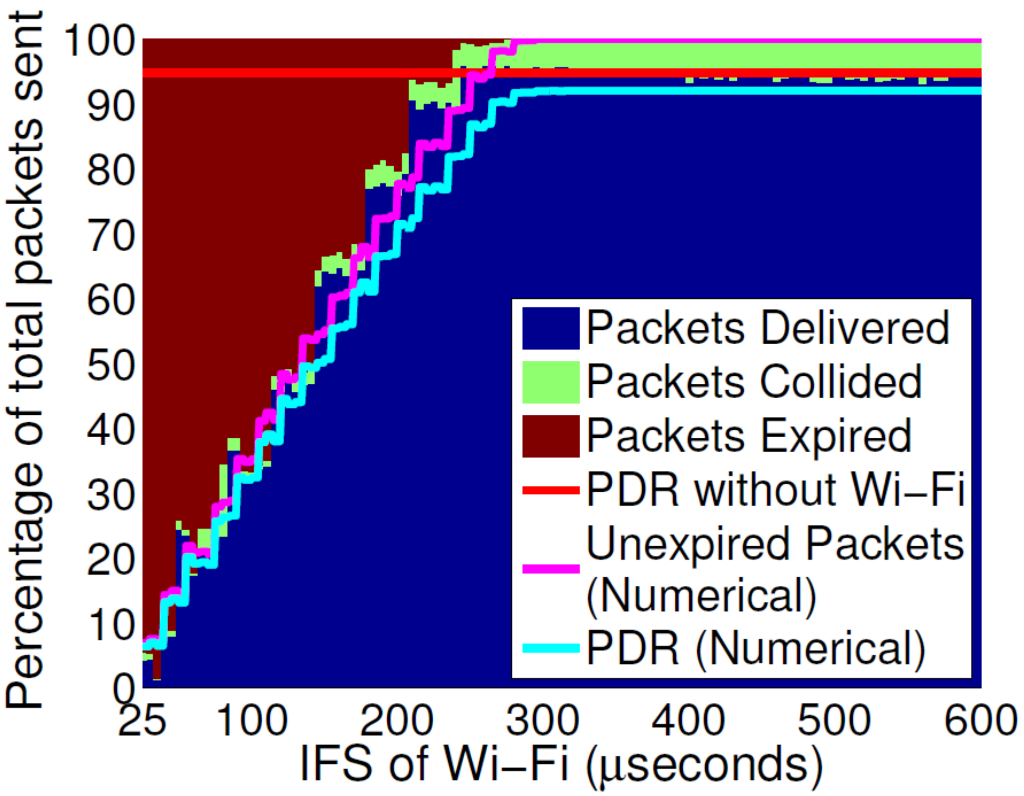

Simulation Topology

30 vehicles/km, Sensing Range = 300

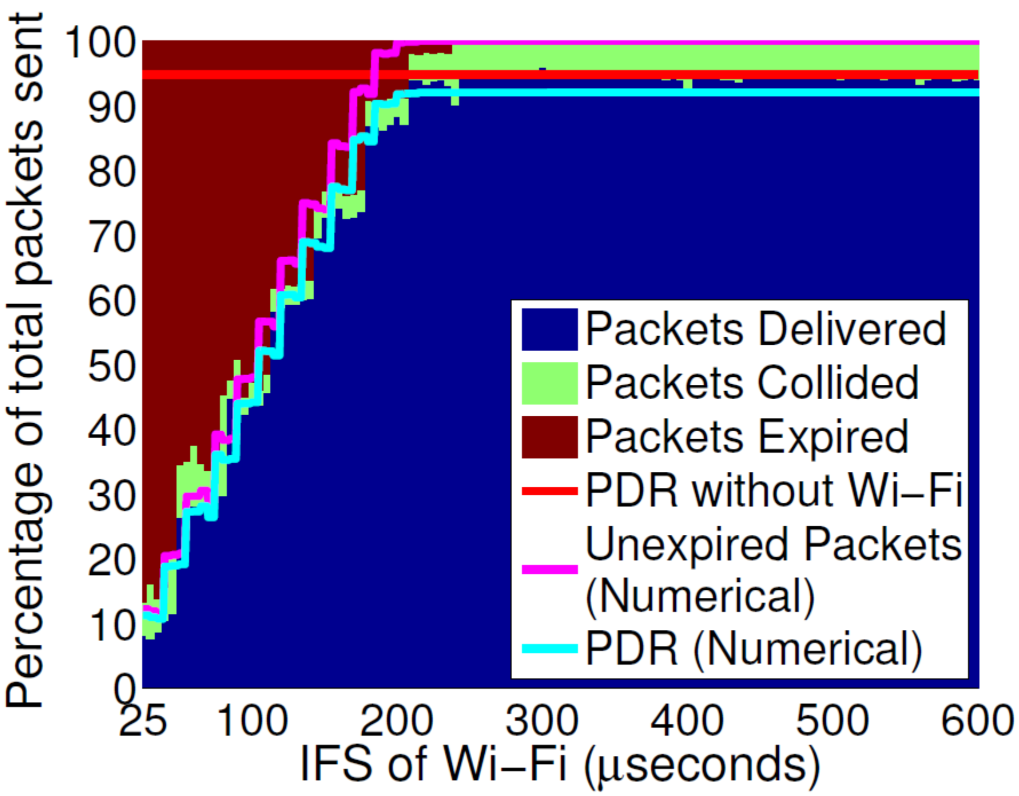


# Simulation Results – Impact of Sensing Sensitivity

30 vehicles/km, Sensing Range = 300

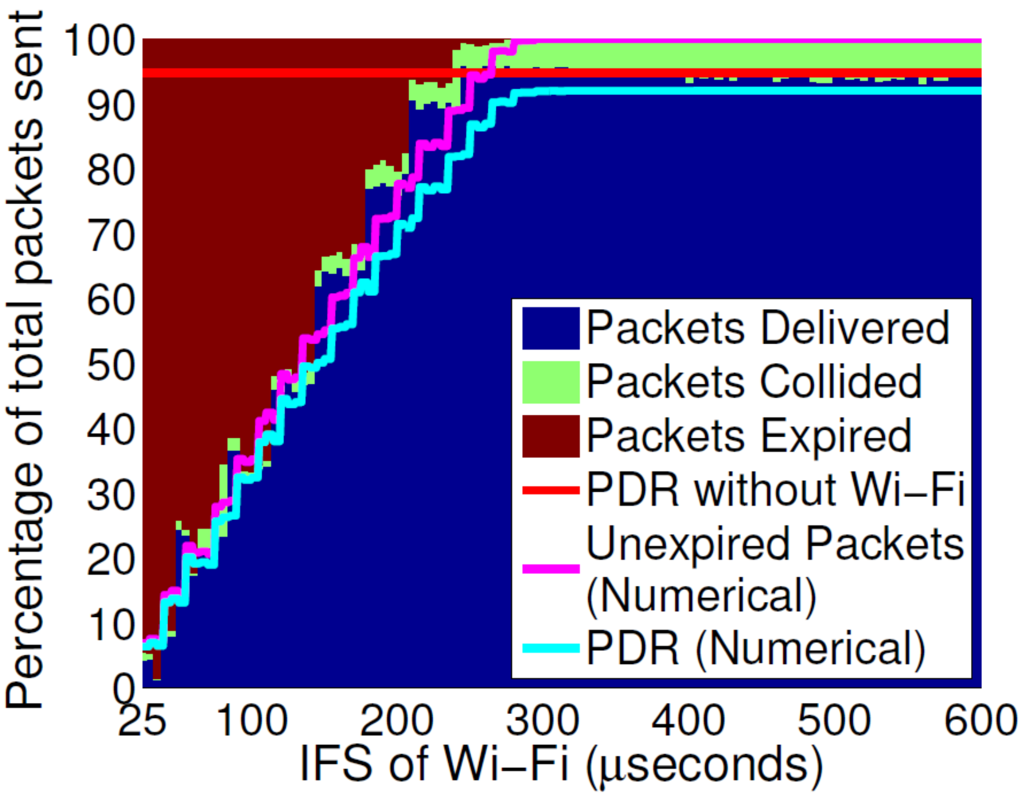



30 vehicles/km, Sensing Range = 500

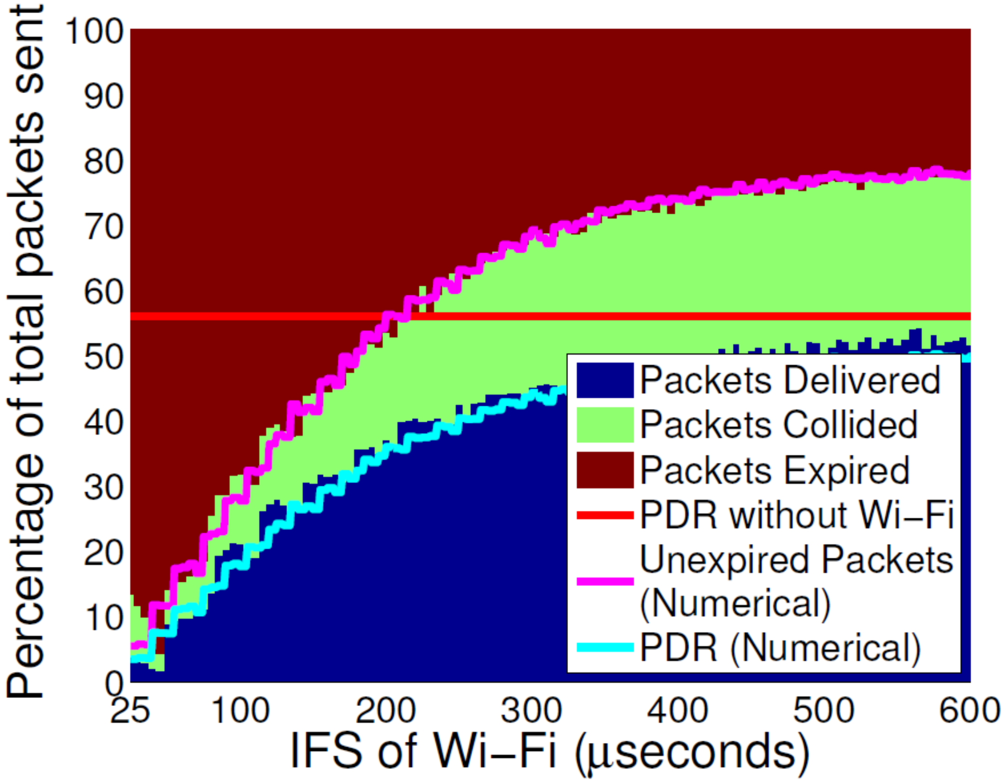


# Simulation Results – Impact of number of vehicles

30 vehicles/km, Sensing Range = 300

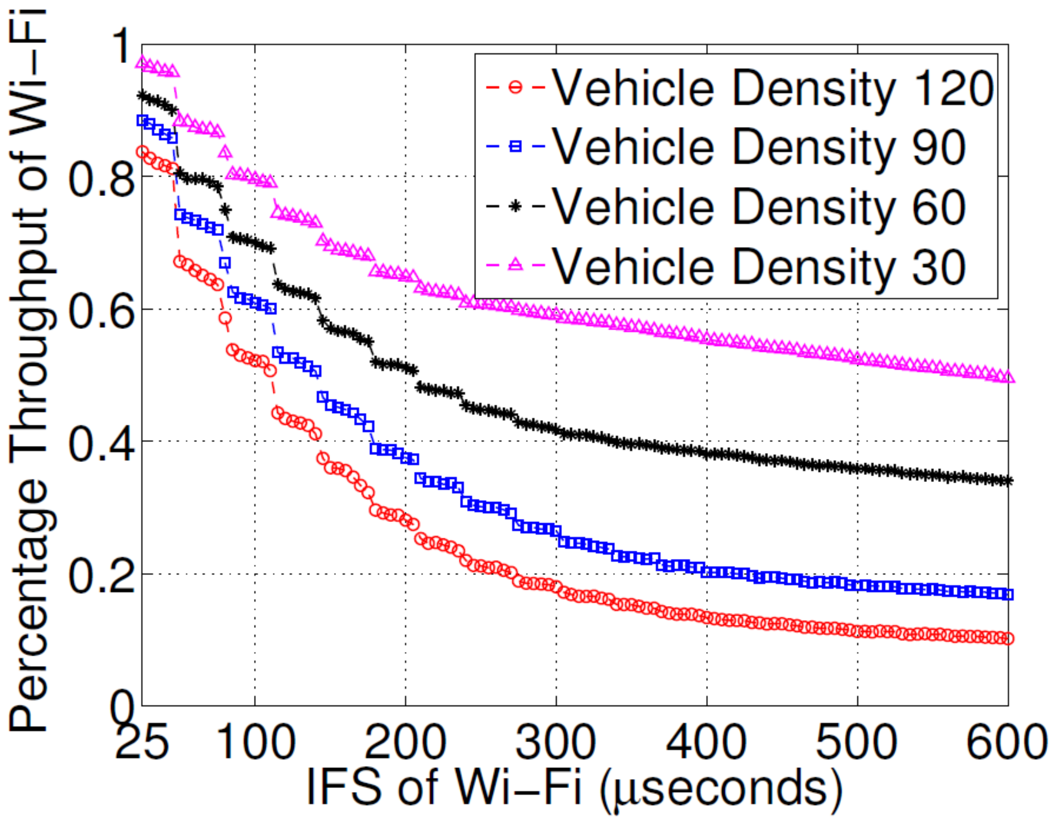



120 vehicles/km, Sensing Range = 300

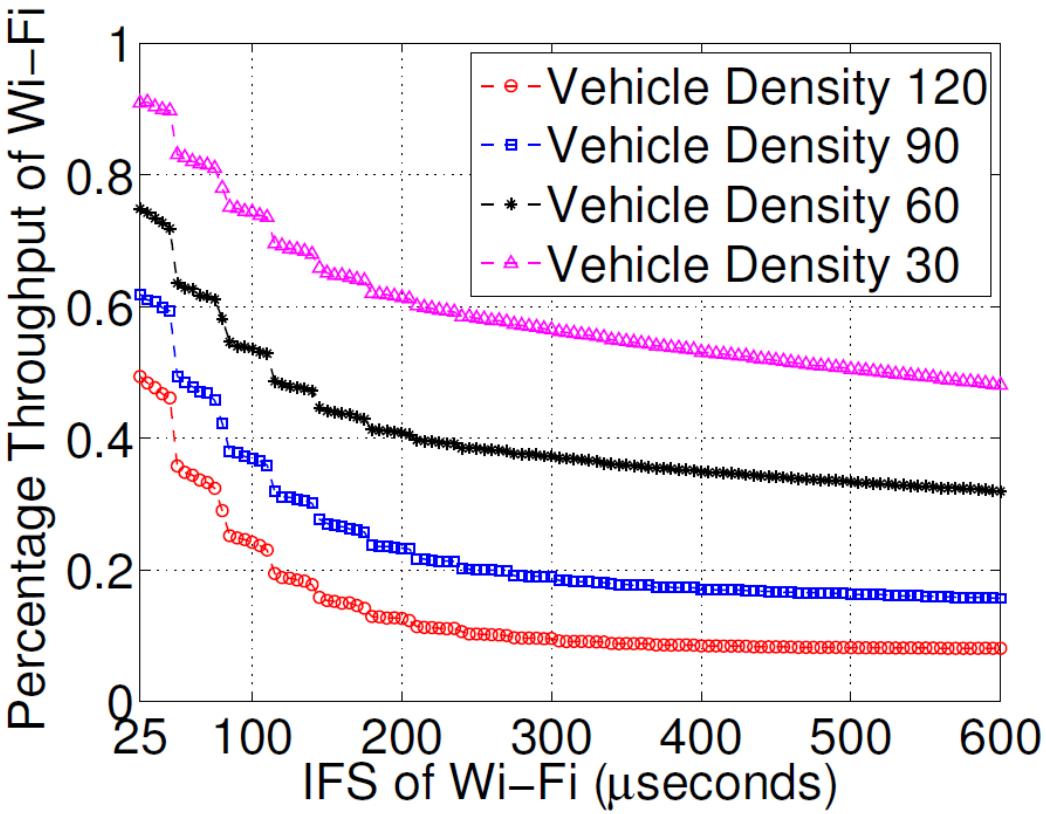


# Simulation Results – Impact on Wi-Fi

Sensing Range = 300




Sensing Range = 500



# Take-away Points

If default Wi-Fi parameters are used, performance of DSRC nodes is significantly degraded

- Need for increased Wi-Fi IFS

Wi-Fi devices need not back-off for arbitrarily large times after sensing DSRC activity

- PDR of DSRC devices saturates after a certain threshold Wi-Fi IFS value
- The threshold IFS value depends on vehicle density
- Wi-Fi performance can be un-acceptable for certain applications

Sensing Range of Wi-Fi devices must be larger than its transmission range

- Larger the sensing range, better the DSRC performance
- Larger the sensing range, poorer the Wi-Fi performance

# Conclusions

We provide insights on adjustment of two key Wi-Fi parameters to enable harmonious DSRC-Wi-Fi coexistence

- Wi-Fi IFS
- Wi-Fi Sensing Range (sensing sensitivity)

Corresponding to the vehicle density, there is a threshold Wi-Fi IFS value beyond which Wi-Fi transmissions do not impact DSRC system performance

- A look-up table based approach can be used

Wi-Fi performance affected, but our approach is more viable than Tiger Team’s proposal.

Thank You for listening!

# Simulation Parameters

| Parameter | Value |
|---|---|
| **Road** | |
| Length of the road | 1000 meters |
| Vehicle densities | {30,60,120} vehicles/km |
| Number of lanes | 6 |
| Lane width | 3 meters |
| **DSRC** | |
| Transmitter Gain | 10 dB |
| Receiver Gain | 4.3 dB |
| Transmission Range | 300 meters |
| Sensing Range | 300 meters |
| Packet Length | 500 bytes |
| Data Rate | 6 Mbps |
| PIFS | 45 $\mu$seconds |
| Slot Duration ($\sigma$) | 16 $\mu$seconds |
| Contention Window | 127 |
| Inter-Broadcast Interval | 0.1 seconds |
| Distance between Tx & Rx | 50 meters |
| **IEEE 802.11ac** | |
| Transmitter Gain | 10 dB |
| Receiver Gain | 4.3 dB |
| Transmission Range | 300 meters |
| Sensing Range | {300,400,500} meters |
| Packet Length | 10,800 bytes |
| Data Rate | 54 Mbps |
| IFS | 23 to 2032$\mu s$ (23 to CW $\cdot\ \sigma$) |
| Distance from DSRC | 150 meters |

Different from standard, set CW of DSRC to be 127, because pointed out in [4], CW=7 is far away from optimal.

[4] R. STANICA, E. CHAPUT, AND A.-L. BEYLOT, "REVERSE BACK-OFF MECHANISM FOR SAFETY VEHICULAR AD HOC NETWORKS," AD HOC NETWORKS, VOL. 16, PP. 210–224, 2014.

# Monte Carlo Sampling

**Algorithm 1** Monte Carlo sampling algorithm

**Input:** $\text{IFS}_2$ of 802.11ac, PIFS, CW
**Output:** $P_c, P_{\text{tran}}$.
Define $k = \lfloor \frac{\text{IFS}_2 - \text{PIFS}}{\sigma} \rfloor$, $l = \lfloor \frac{\text{CW}}{k} \rfloor$, $\beta_1 = 2\lambda R$, $\beta_2 = 2\lambda S$
Initialize $P_{\text{tran}} = 0$,
$\gamma_1 = \min\{\beta_1, \beta_2\}$, $\gamma_2 = |\beta_1 - \beta_2|$
**for** $t = 1, 2, \cdots, T$ **do**
Sample $X_1 \sim \text{Poi}(\gamma_1)$, $X_2 \sim \text{Poi}(\gamma_2)$, $N = X_1 + X_2$
Sample $B^{(i)} \sim \text{unif}[0, \text{CW} - 1]$, $i = 1, 2, \cdots, N$
Add $B^{(0)} = 0$, let $\mathbf{B} = [B^{(0)}, B^{(1)}, \cdots, B^{(N)}]$
$\mathbf{B}' = \mathbf{B}[1, 2, \cdots, X_1]$
**if** $\beta_1 > \beta_2$ **then**
Find the indexes of $B^{(1)}$ in $\mathbf{B}$ and $\mathbf{B}'$, denoted as $I_1$ and $I_2$
**else**
Find the indexes of $B^{(1)}$ in $\mathbf{B}$ and $\mathbf{B}'$, denoted as $I_2$ and $I_1$
Sort $B^{(0)}, \cdots, B^{(N)}$ in ascending order $B_0, \cdots, B_N$
Initialize $\mathbf{Q} = [0, 0, \cdots, 0]_{1 \times l}$.
**for** $j = 1, 2, \cdots, l$ **do**
**for** $m = 1, 2, \cdots, N_2$ **do**
**if** $k \cdot j \leq B_m - B_{m-1} < k \cdot (j+1)$ **then**
**if** $m \leq I_2$ **then**
$\mathbf{Q}(j) = \mathbf{Q}(j) + 1$
$n_{ac} = [1, 2, \cdots, l] \cdot \mathbf{Q}^T$
**if** $n_{ac} \cdot T_2 + I_1 \cdot (T_1 + \text{PIFS}) + B^{(1)} \cdot \sigma \leq T_c$ **then**
$P_{\text{tran}} = P_{\text{tran}} + 1$
**if** $B^{(1)} == B_{I_1+1}$ or $B^{(1)} == B_{I_1-1}$ **then**
$P_c = P_c + 1$
$P_c = P_c / P_{\text{tran}}$, $P_{\text{tran}} = P_{\text{tran}} / T$