Effect of Antenna Placement and Diversity on Vehicular Network Communications

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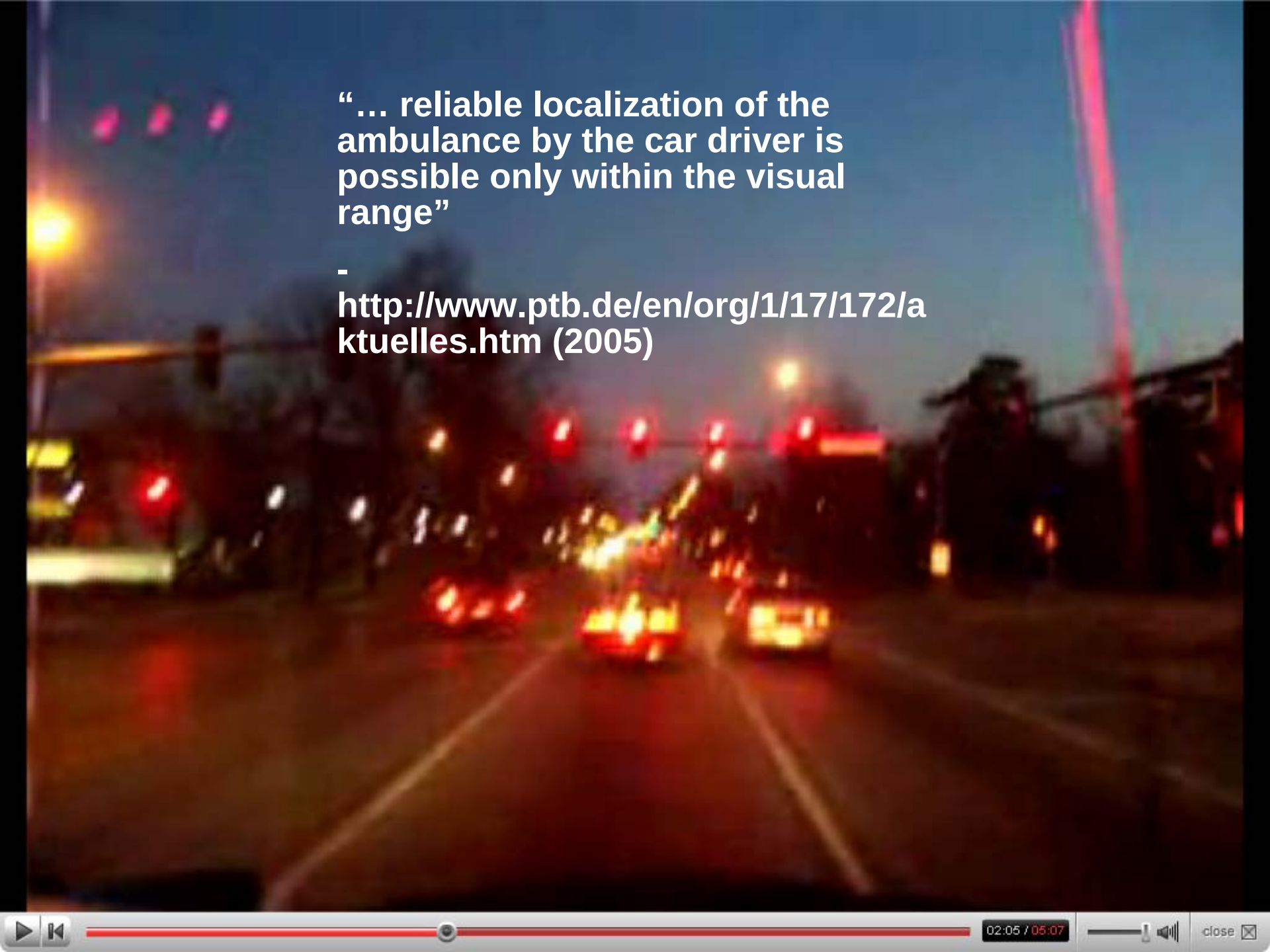
“… reliable localization of the ambulance by the car driver is possible only within the visual range”
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Motivation

- Vehicle-to-Vehicle ad-hoc networks
  - **Safety Applications**
    - Emergency Vehicle approaching warning – "**Seconds Can Save a Life!"**
    - Collision Avoidance/Warning
  - **Information/ Entertainment applications**
    - Traffic Information
    - Music updates/ Video Downloads
- Application specific reliability, latency and bandwidth requirements!
- DSRC (Dedicated Short Range Communications)
    - IEEE 802.11p @ 5.9Ghz
- **Need to evaluate 802.11p in vehicle-to-vehicle setups.**

In *this* ***work***

- **Show *effect of antenna placement and car geometry on a car-to-car link* in the 5Ghz band**
  - **Most antenna positions show distorted antenna patterns.**
- **Demonstrate *a multi-radio packet selection diversity scheme***

Related Work

- 802.11 measurement studies in **indoor [**D. Eckhardt et. al**]** (wlans) **and stationary outdoor [**C. Reis et al.**]** (phy layer behavior of packet reception and carrier sense)**, [**D. Aguayo et. al**]** (Roofnet) **environments.**
- Studies that **characterize throughput, latency and packet loss** at the transport layer for V2V and R2V communications **[**H. Wu, M. Palekar et. al**] [**F. Hui and P. Mohapatra**]**.
- **Channel models for V2V** using empirical data in the **60Ghz** band **[**S. Takahashi et. al**]**.
- **Earlier studies** of placement effects on antenna patterns **in the 900Mhz band [**R. L. Jesch**] and at 2Ghz [**P. Eskelinen and A. Salpala**]**.

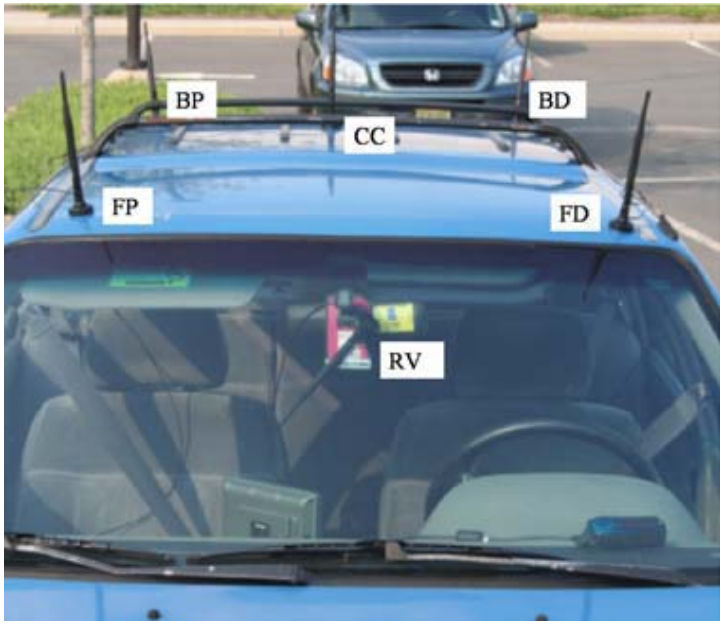
Methodology

Choice of Radio

- Used **802.11a** cards ***instead of*** pre-standard **802.11p** radios
  - Ease of availability of 802.11a cards
  - Modulation/ Coding similar
  - Difference in frequency band (5.18Ghz vs 5.9 Ghz)
  - 802.11p OFDM has larger guard intervals than 802.11a (1.6μs vs. 0.8μs)
    - ***802.11a performance likely a lower bound for 802.11p***

Hardware

- ORBIT Nodes
  - 1 Ghz CPU/ 512MB RAM/ 20GB hard disk
  - Two 802.11a/b/g radios based on Atheros 5212 chipset.
- Garmin eTrex GPS
- 2.4/5Ghz band folded dipole antennas
- *RX Car* (The Receiver Car)
  - **6 antennas (Three ORBIT Nodes)**
    - **Five on car roof**
    - **One inside attached to the rear-view mirror.**
- *TX Car*
  - **One antenna**
    - **Roof top, center.**



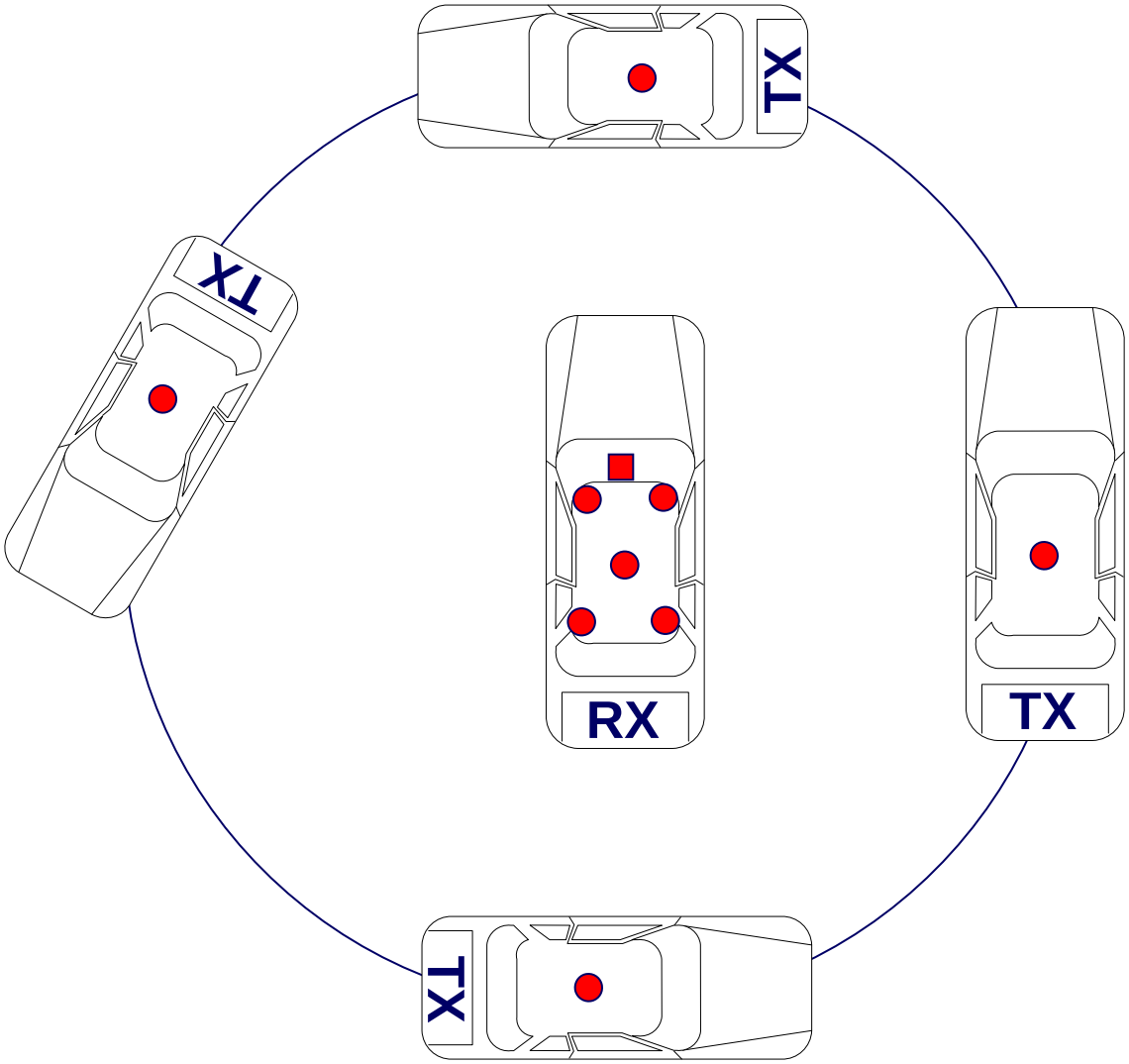
Software

- Debian GNU/Linux with the 2.6 kernel
- Transmit 1000 ping packets per second
  - 6Mbps PHY rate
  - 52 byte ICMP payload
  - Payload modified to include 32 bit per packet sequence number
- Receiver 802.11a in monitor mode
  - Use the ***tcpdump*** utility to log all sniffed packets.
  - Obtain per packet RSSI and PER.
- Log GPS information at TX and RX

Experiments & Results

Effect of car geometry on Antenna patterns

- Open Space (Livingston Parking Lot, Rutgers Univ.)
  - **LOS, static**
  - **No significant scatterers and reflectors in vicinity**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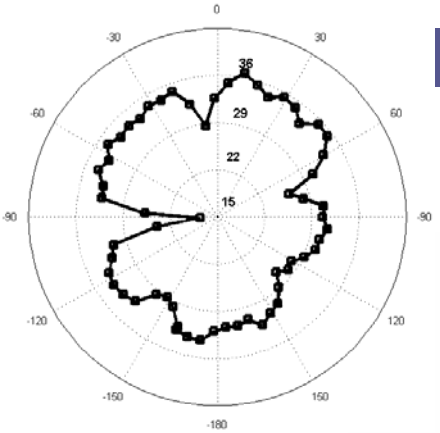
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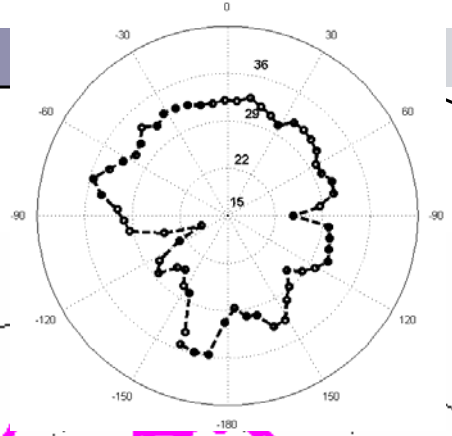
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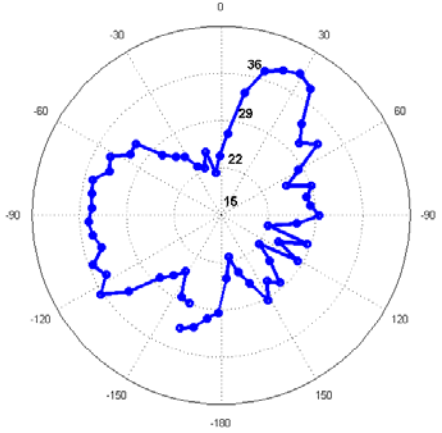
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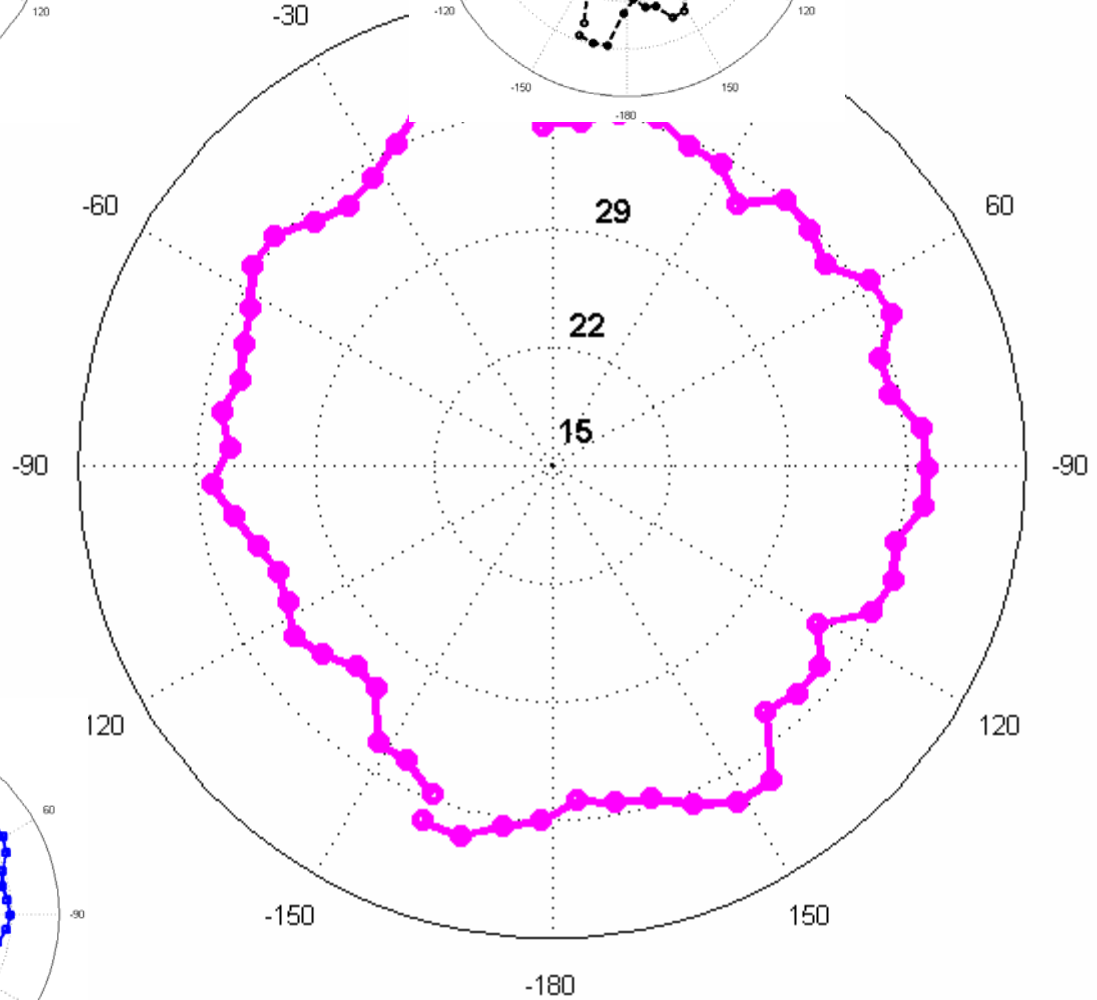
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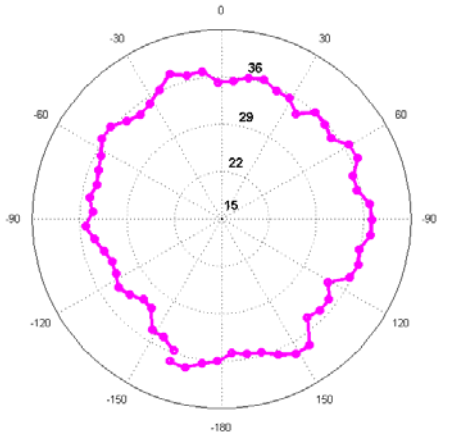
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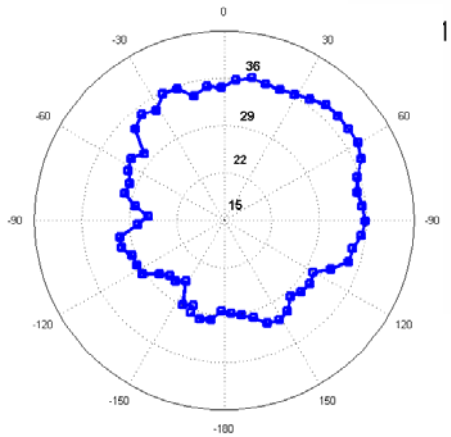
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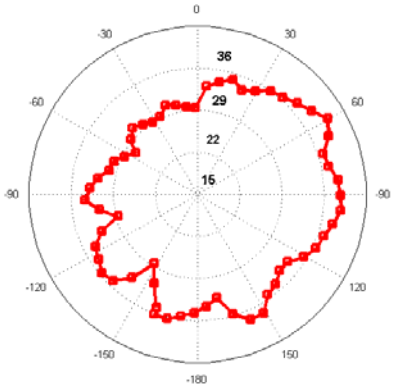
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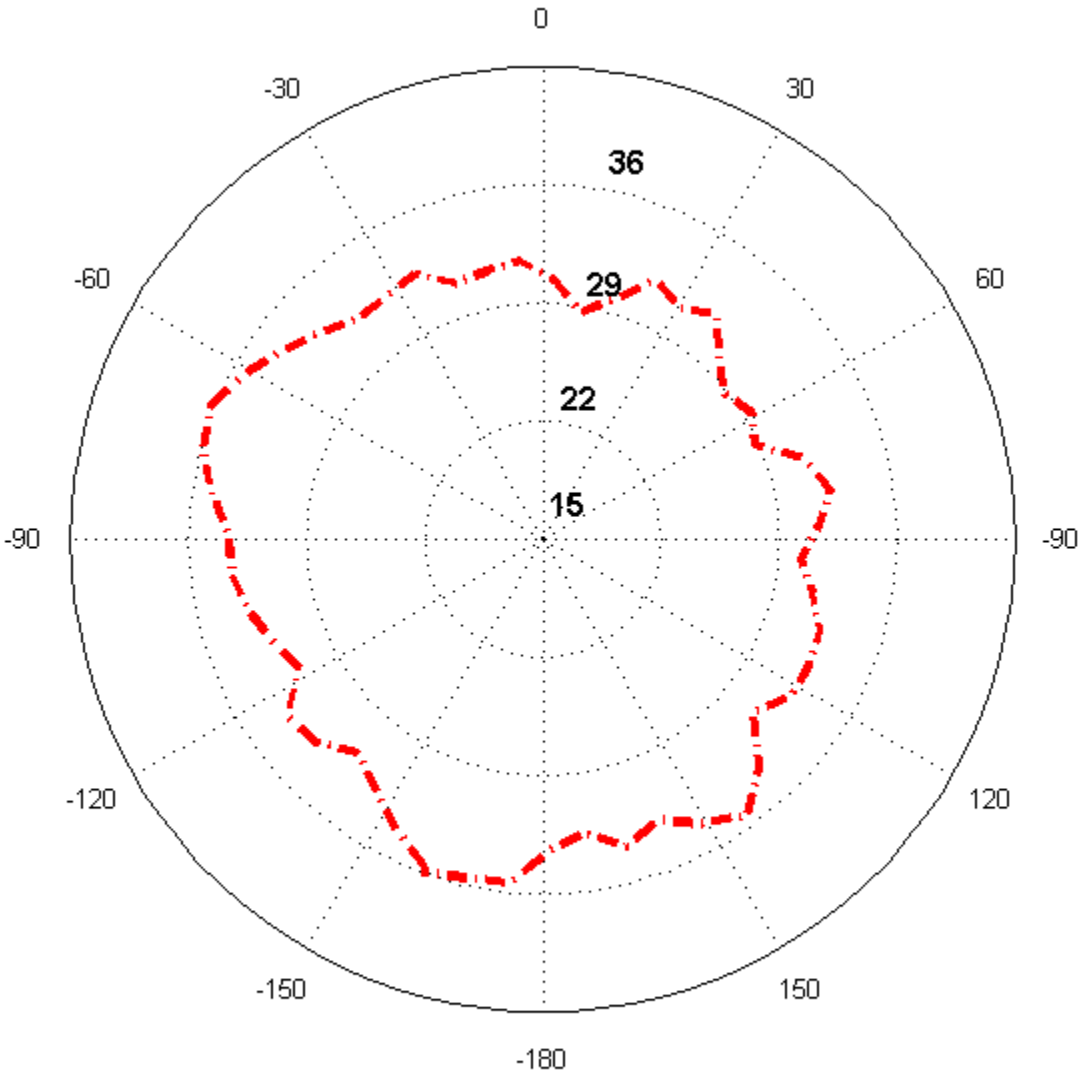
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Effect of car geometry on Antenna patterns – Results contd.

- Most **“car antennas”** show **strong asymmetric patterns**, with up to 10dB variance in RSSI with angle.
  - Effect of Car Geometry!
- The CC mounted antenna shows the most omni-directional pattern
  - Apparently the top-center position is also preferable in the 5 GHz band

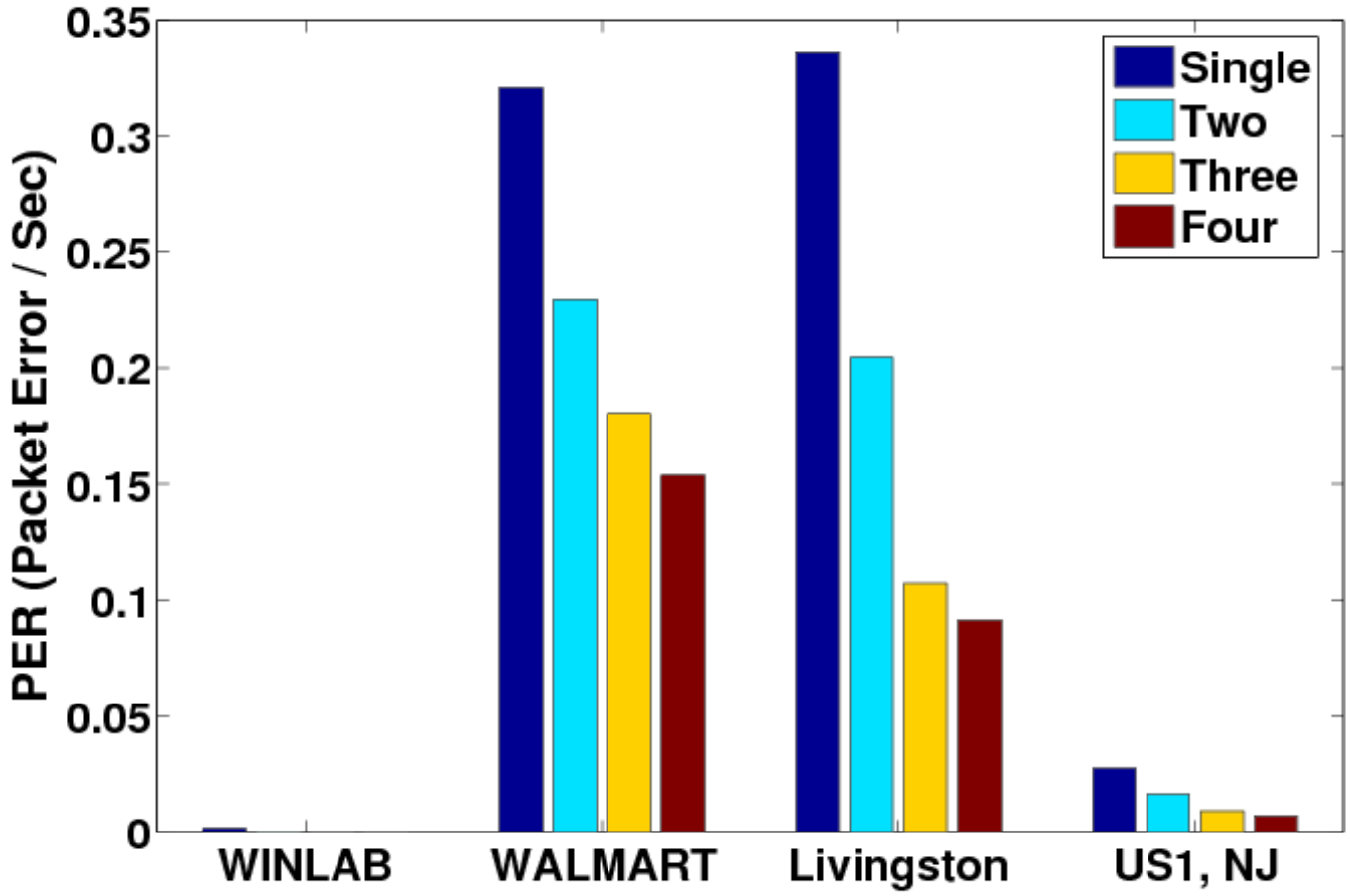
Parking Lot & Freeway Exp – Results contd.

- Difference in the performance of the **best** and the **worst** performing ***antenna position*** at ***all the parking lots is between 25-30%***.
  - The *effect of car geometry* on antenna performance did not vary much with changing propagation environments!
- **There is no single best antenna position.**

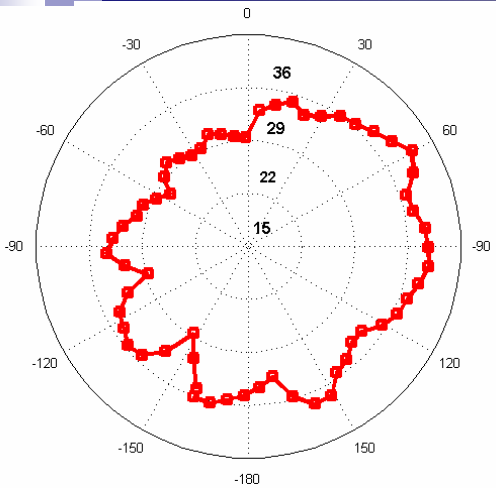
Diversity Gains

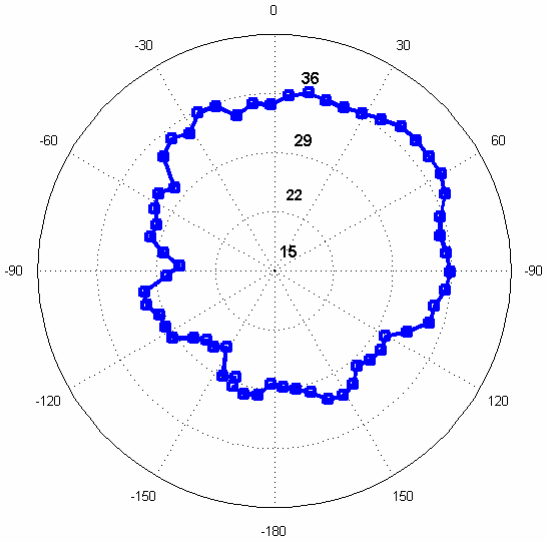
- Typically LOS environments don't see any diversity gains.
- Collocation of antennas rules out any gains due to alleviation of shadowing!
- However, effects of car geometry can be alleviated using diversity.
- *Multi-Radio Packet Selection (MRPS)*
  - **Similar to multi-radio diversity**
  - **For a data packet (MAC and above) to be received**
    - At least one of the selected RX antennas/radios should receive the packet
    - Any packet received is correct as packet selection is above MAC.
  - **Select only one received instance of a packet**

Diversity Gains - Results

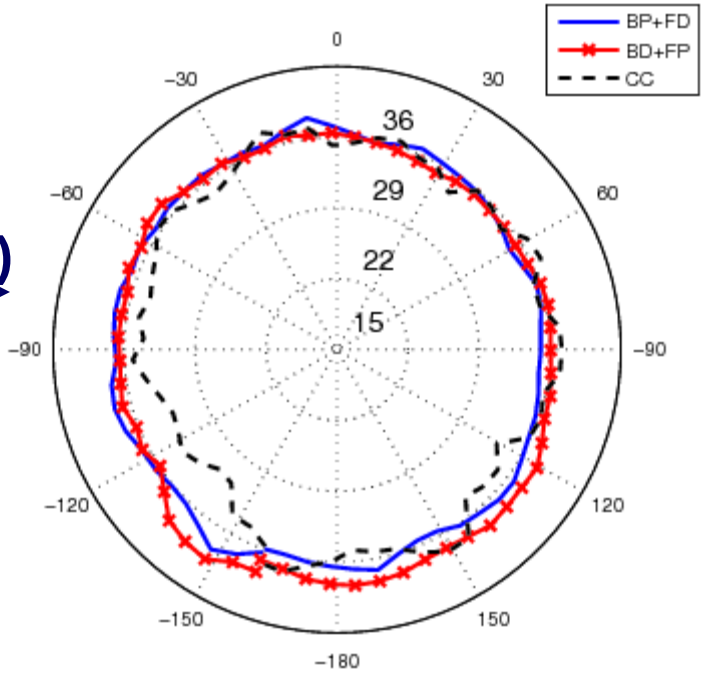


- **Diversity gains are achieved in the LOS, NLOS, static and dynamic freeway environments.**

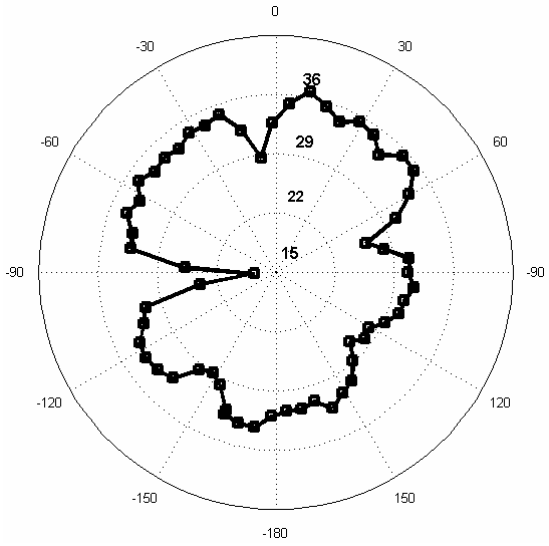


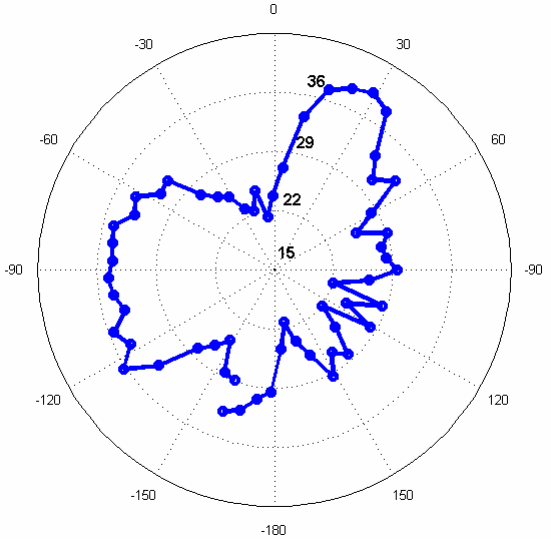


MRPS(BP, FD)



MRPS(BD, FP)





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Omni-directional-*ization* of antenna patterns

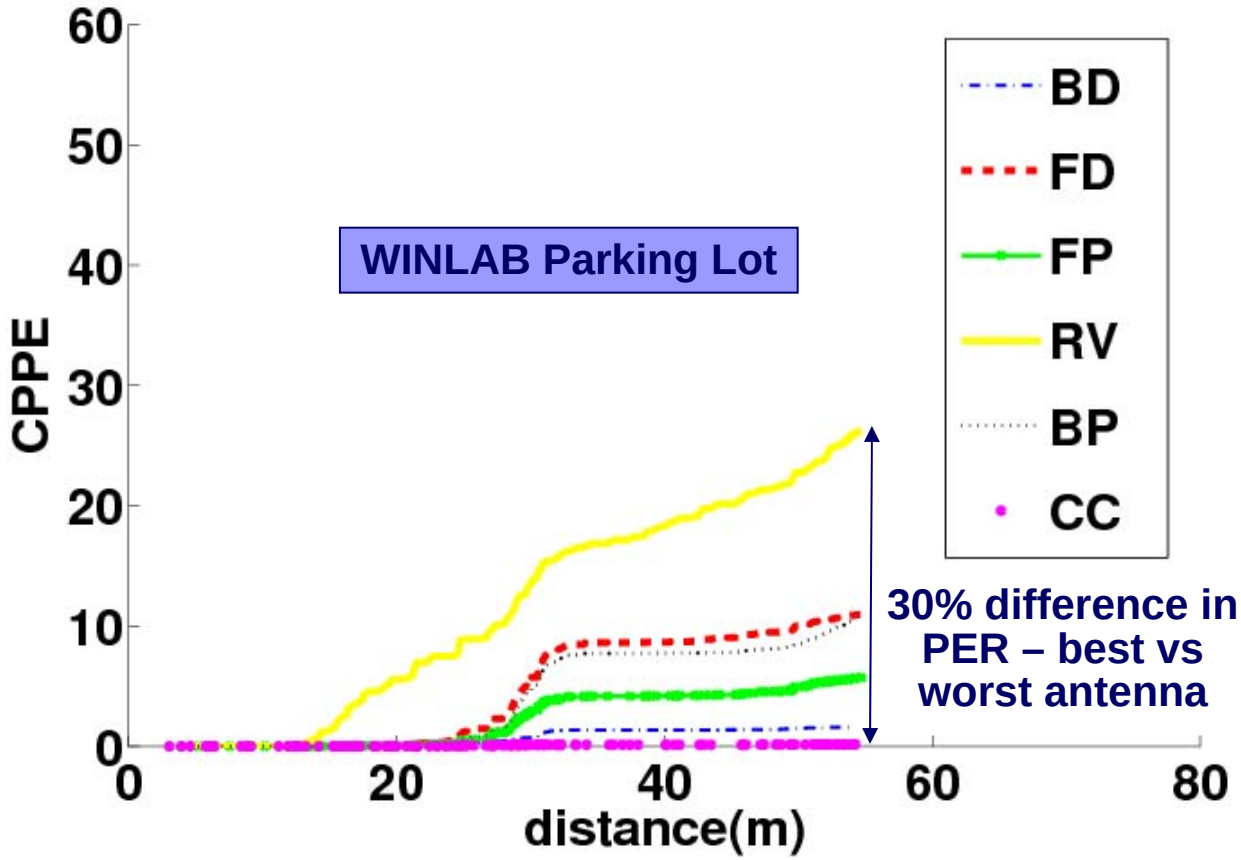
Conclusion

- Gain patterns of omni-directional antennas become asymmetric in many mounting positions. A spread of up to 15db was observed for some.
- Center mounting provides a very close (within 3db) to omni-directional pattern.
- Between antenna positions a 25-30% difference in PER performance was observed in our experiments across propagation environments.
- A packet level diversity technique can provide 10-25% gains in packet reception rate and 2-5dB gains in received packet RSSI and alleviate the *effect of vehicle geometry*. It provides an alternative if center mounting is not feasible.

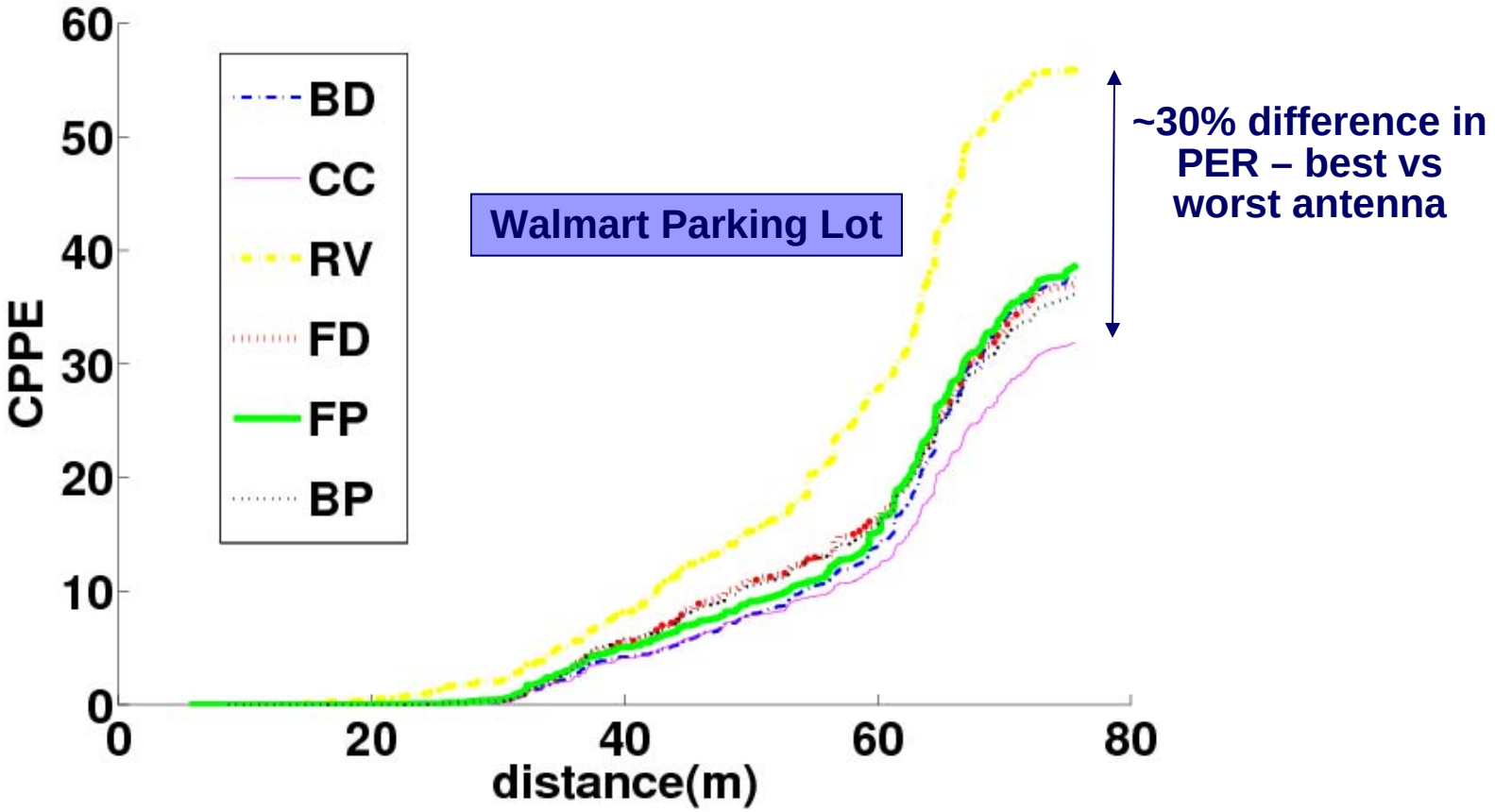
Default Parameters

Parameter	Value
Wireless Card	Atheros 5212 chipset
Driver	MadWifi
MAC and PHY protocol	802.11a
Frequency	5.18Ghz (20Mhz B/W)
Transmit Power	40mW
Antenna Type	Folded Dipole
Antenna Gain	3dBi
PHY Data Rate	6Mbps
ICMP Payload	56 bytes
Transmission Rate	1000 packets per second

Parking Lot & Freeway Exp – Results contd.



Parking Lot & Freeway Exp – Results contd.



Effects Of Antenna Placement on Vehicular Protocol Design

- Simulation (ns-2)
  - **Number of nodes:** 100, Area - 2Km X 2Km, Speed: 40m/s
  - **Mobility model:** random waypoint
  - **Transmission range:** 250m, Carrier sense range:550m.
  - **Packet size:** 100 bytes, sent periodically (period selected randomly from (0.75, 1.25) seconds),
  - **Simulation time:** 500 seconds.
  - **Propagation Model:** Two ray model gains offset by the antenna pattern gains for the angle of arrival and antenna.
  - **Packet Reception:** A packet will be received if the resulting signal strength is greater than a reception threshold.

Simulation Results

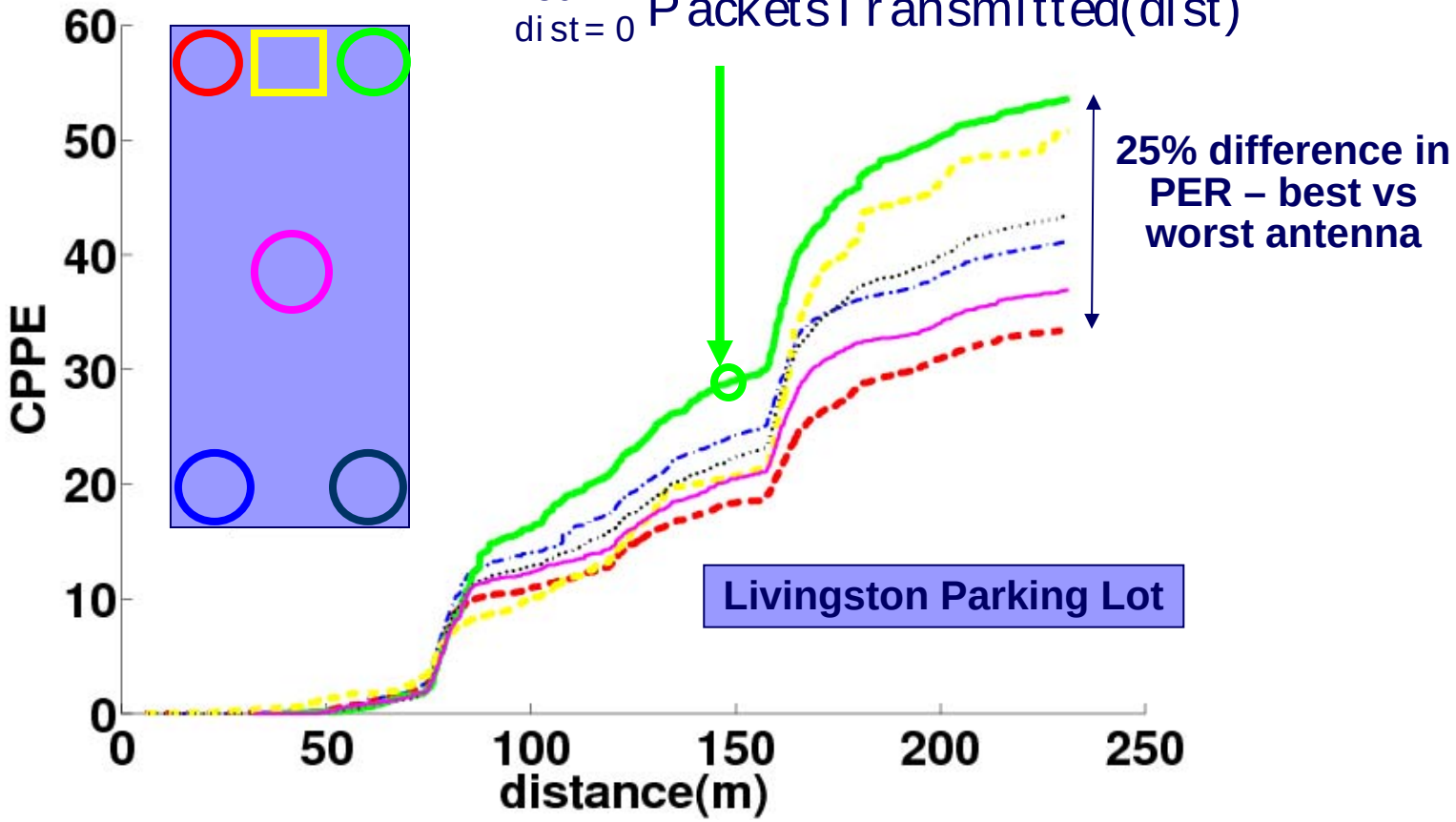
Antenna Position	No. of pkts received	% pkts received
FP	79437	25.34
RV	138814	44.28
BP	141392	45.11
BD	143005	45.62
FD	164807	52.58
Tripod	182631	58.26
CC	226213	72.17
Ideal Antenna	313425	100.00

Discussion

- At MAC the asymmetric RSSI patterns could lead to
  - Hidden Nodes
  - Node Deafness
- At the network layer neighbor discovery could be affected.

Parking Lot & Freeway Exp - Results

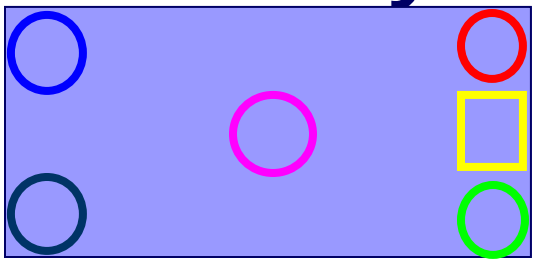
$$\frac{\sum_{dist=0}^{150} NumberOfPacketsLost(dist)}{\sum_{dist=0}^{150} PacketsTransmitted(dist)}$$



Diversity Gains

Maximum Distance between antennas is < 2m

The co-located antennas are similarly shadowed.



- **The antenna separation (many wavelengths) => fading at them is uncorrelated!**
- **Theoretically, *symbol level* combining/selection will give diversity gains that alleviate small scale fading.**

- **In the absence of car geometry effects only small scale fading will lead to packet errors.**
- **If that were the case the average packet error rate at all antennas must be nearly the same.**

- *Multi-Radio Packet Selection (MRPS)*
  - **Similar to multi-radio diversity**
  - **For a data packet (MAC and above) to be received**
    - At least one of the selected RX antennas/radios should receive the packet
    - Any packet received is correct as packet selection is above MAC.
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