

1. Enumerate the main changes on the physical layer to fulfill the V2X-requirements
 - Operation on an exclusive frequency band at 5.9 GHz
 - 10 MHz physical layer (PHY) mode with all timings doubled for greater robustness against multipath fading
2. List the main changes on the MAC layer
 - No synchronization, authentication and association as these procedures are very time sensitive
 - A new operation mode in the MAC layer: *outside-the-context of BSS* (OCB)
 - Enhanced Distributed Channel Access (EDCA) providing Quality of Service (QoS) that allows to prioritize safety messages
3. What is the motivation behind the operation mode *outside-the-context of BSS*?
 - Allows immediate communication without connection setup
 - Stations can operate without being part of a BSS (basic service set)
 - No authentication/association procedures as a station may never join a BSS
4. Explain briefly the advantages of doubling timing parameters on the physical layer
 - It ensures robustness against the effects of mobility as doubling the guard interval in time domain will reduce the inter-symbol interference (ISI) caused by multipath propagation
5. What is the main drawback of increasing a frame duration in time domain?
 - The increased frame duration makes the signal more sensitive against fast-fading effects
6. What is the delay spread?
 - Total elapsed time between the first (direct line-of-sight path) and last echo of a same signal
7. What is the source of fast fading?
 - Fast fading originates due to effects of constructive and destructive interference patterns which is caused due to multipath
8. List the four wave propagation characteristics specific to V2X communication
 - Reflection
 - Diffraction

- Scattering
 - Wave guiding
9. When does scattering occur?
- Scattering occurs when a signals wavelength is larger than pieces of a medium. The wave is reflected into multiple directions
10. What is multipath propagation?
- Multipath propagation is the propagation phenomenon that happens when a same signal arrives at the receiver through different paths and hence with different delays or phase shifts
11. How does increasing the symbol length affect the communication performance?
- Increasing symbol length makes the physical layer robust to maximum delay spreads
12. What are the advantages of Orthogonal Frequency-Division Multiplexing (OFDM)?
- Combats inter-symbol interference
 - Provides robustness against severe channel conditions such as multipath fading
 - Increases spectral efficiency as inter-carrier guard bands are not required
13. How does OFDM deals with subcarriers overlaps?
- Subcarriers do not interfere at the center frequencies of other subcarriers
 - Contributions of each subcarrier are zero at multiples of the subcarrier spacing, i.e., the center frequencies of adjacent subcarriers
14. What are the factors that cause inter-symbol interference (ISI)?
- See lecture slide 16
15. What is the role of the preamble?
- A bit sequence used to notify receivers of the eminent arrival of a frame
16. What is the content of the physical layer convergence procedure (PLCP)
- Provides details on frame length, modulation and coding rate
17. List the sequences during frame reception
- See lecture slide 20
18. How does frame body capture effect works?

- See lecture slide 21
19. How does frame body capture effect reduces the impact of hidden terminal?
 - At least one frame (with stronger signal) originated by a hidden station would probably be successfully received even in an overlapping situation
 20. What is a channel propagation model?
 - Mathematical representation of the effects of a communication channel through which wireless signals are propagated
 21. Briefly provide two approaches for channel modeling
 - Deterministic
 - Stochastic
 22. What is the difference between NLOS and OLOS?
 - Non-line-of-sight (NLOS): Situation where the line-of-sight between the TX and RX is completely blocked by a larger object, e.g. a building
 - Obstructed-line-of-sight (OLOS): Situation where a line-of-sight between the TX and RX is obstructed partially by another object (dynamic blockages e.g. other vehicles)
 23. Briefly present the Two-Ray interference model
 - Deterministic channel model
 - A physically more accurate approximation of path loss considering the phase difference of two interfering rays: direct line of sight and reflected non line of sight path
 24. Derive the phase difference as well as the angle of incidence of the Two-Ray interference model

Solution: By considering the drawing on figure ??, we could derive the following

- Length of the direct line-of-sight ray

$$d_{LOS} = \sqrt{(h_t - h_r)^2 + d^2}$$

- Length of the ground-reflected ray

$$d_{Ref,1} + d_{Ref,2} = \sqrt{(h_t + h_r)^2 + d^2}$$

- Path-length difference between both waves

$$\Delta d = d_{Ref,1} + d_{Ref,2} - d_{LOS} = \sqrt{(h_t + h_r)^2 + d^2} - \sqrt{(h_t - h_r)^2 + d^2}$$

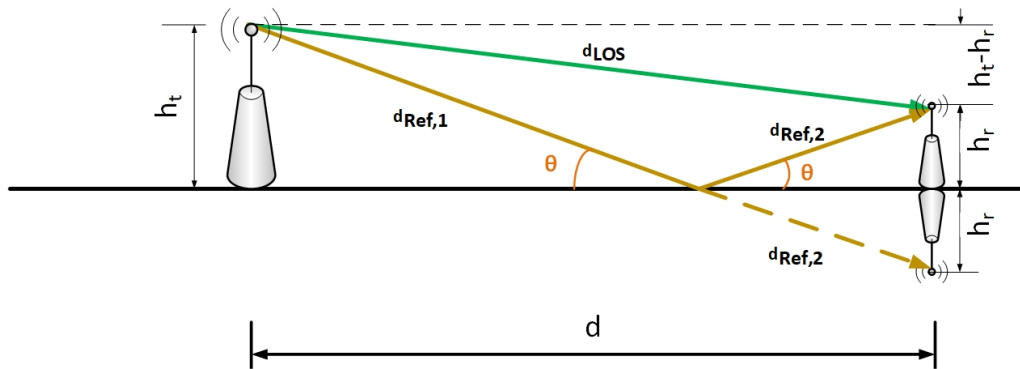


Figure 1: Simplification of the Two-Ray interference model

- Phase difference between the waves is $\Delta\phi = \frac{2\pi\Delta d}{\lambda}$
- Angle of incidence is the angle between the direct and the reflected ray

$$\sin \theta = \frac{h_t + h_r}{d_{Ref,1} + d_{Ref,2}} = \frac{h_t + h_r}{\sqrt{(h_t + h_r)^2 + d^2}}$$

$$\cos \theta = \frac{d}{d_{Ref,1} + d_{Ref,2}} = \frac{d}{\sqrt{(h_t + h_r)^2 + d^2}}$$

25. What is the motivation of providing an approximation of Two-Ray interference model?

- Enable fast simulation but with the best level of accuracy

26. Briefly present the 3D Ray-optical channel model

- Deterministic channel modelling approaches using 3D ray-optical algorithms
- Each ray is modelled individually considering wave reflection, diffraction and scattering

27. What are the limitations of 3D Ray-optical channel model?

- High computational efforts required
- Couldn't ensure real time or near real time simulation

28. Briefly present the log-normal channel model

- Uses a normal distribution with a fixed variance to distribute reception power
- For every individual transmission the received power is then drawn from a distribution
- Considers additional factors (shadowing) that contribute to path loss such as obstacles, which shield a receiver from all or part of the radiated power

29. Consider the following vehicular network topology shown in Figure 1 where vehicles B, C and D broadcast their frames with a transmission power $P_t = 23$ dBm at the frequency $f = 5.9$ GHz. For the path loss calculation between stations, assume a free space channel model with a path loss exponent of $\alpha = 2.0$.

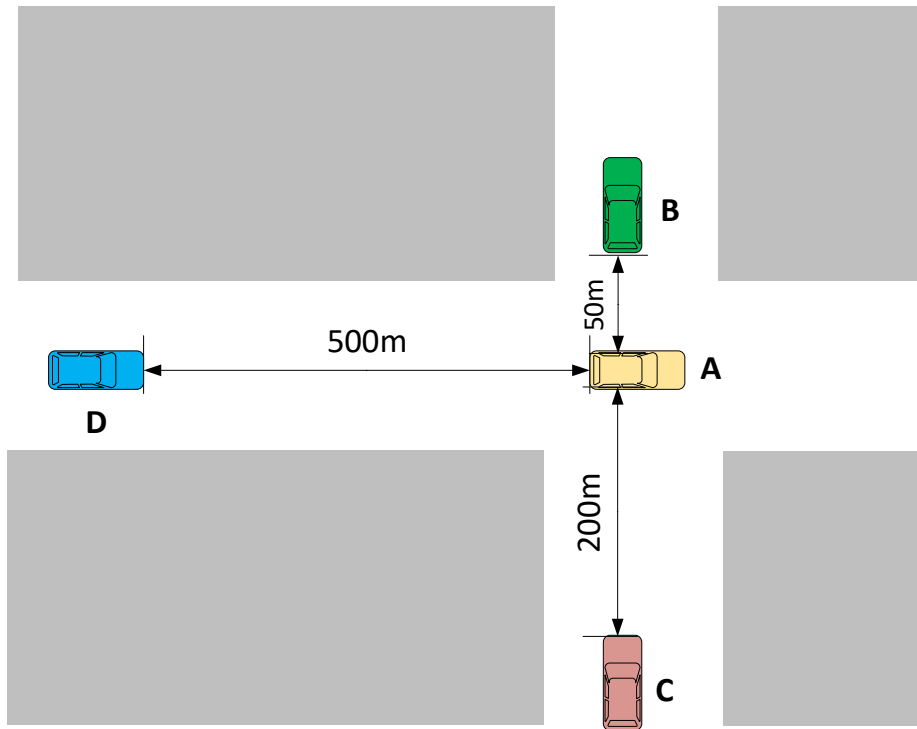


Figure 2: An intersection scenario

- (a) The broadcasting vehicles transmit at different times without frame overlaps at any receiver. Calculate the received power $P_{r,B}$, $P_{r,C}$, and $P_{r,D}$ in dBm at the receiving vehicle A. Assume transmitter/receiver antenna gain $G_t = G_r = 0$ dBi

- Received power

$$P_r = P_t + G_t + G_r - L_{FS}$$

where free space loss component L_{FS} is given as

$$L_{FS} = 10 \log_{10} \left(4\pi \frac{d}{\lambda} \right)^2 = 20 \log_{10} \left(4\pi \frac{d}{\lambda} \right) = 20 \log_{10} \left(\frac{4\pi f}{c} \right) + 20 \log_{10}(d)$$

$$\Rightarrow P_{r,B} = -58.83 \text{ dBm}, P_{r,C} = -70.87 \text{ dBm}, \text{ and } P_{r,D} = -78.83 \text{ dBm}$$

- (b) Now assume that vehicles B and C transmit simultaneously their respective frames B and C which overlap at the receiving vehicle A.

- i. Calculate the signal interference noise ratio (SINR) of each frame considering a noise power $N_0 = -100$ dBm
 - ii. How does the frame body capture help in such a situation?
- Signal interference noise ratio

$$SINR = \frac{P_r}{N_0 + \sum I}$$

where P_r is the power of the incoming signal of interest, I is the interference power of the other (interfering) signals in the network and N is some noise term.

Frame C is the interfering signal for frame B at the receiving vehicle A:

$$SINR_B(mW) = \frac{P_B(mW)}{N_0(mW) + P_C(mW)} = \frac{10^{P_{r,B}/10}}{10^{N_0/10} + 10^{P_{r,C}/10}} = \frac{1.3 \times 10^{-6}}{10^{-10} + 8.16 \times 10^{-8}} = 15.98 \text{ mW}$$

$$SINR_B(dBm) = 10 \log_{10}(15.98) = 12.3 \text{ dBm}$$

Likewise the frame B is the interfering signal for frame C:

$$SINR_C(mW) = \frac{P_C(mW)}{N_0(mW) + P_B(mW)} = \frac{10^{P_{r,C}/10}}{10^{N_0/10} + 10^{P_{r,B}/10}} = \frac{8.16 \times 10^{-8}}{10^{-10} + 1.3 \times 10^{-6}} = 0.0625 \text{ mW}$$

$$SINR_C(dBm) = 10 \log_{10}(0.0625) = -12.04 \text{ dBm}$$

- Although both frames B and C simultaneously arrive at the receiving vehicle A, the frame body capture enables the capability to capture the frame with stronger signal whenever the signal difference is greater than 10 dB

$\Delta P_r = P_{r,B} - P_{r,C} = 12.04 \text{ dB} > 10 \text{ dB} \implies$ Frame B would successfully be decoded by vehicle A