5G 차량통신 pathloss model (3.5GHz, 28 GHz)

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Sample A

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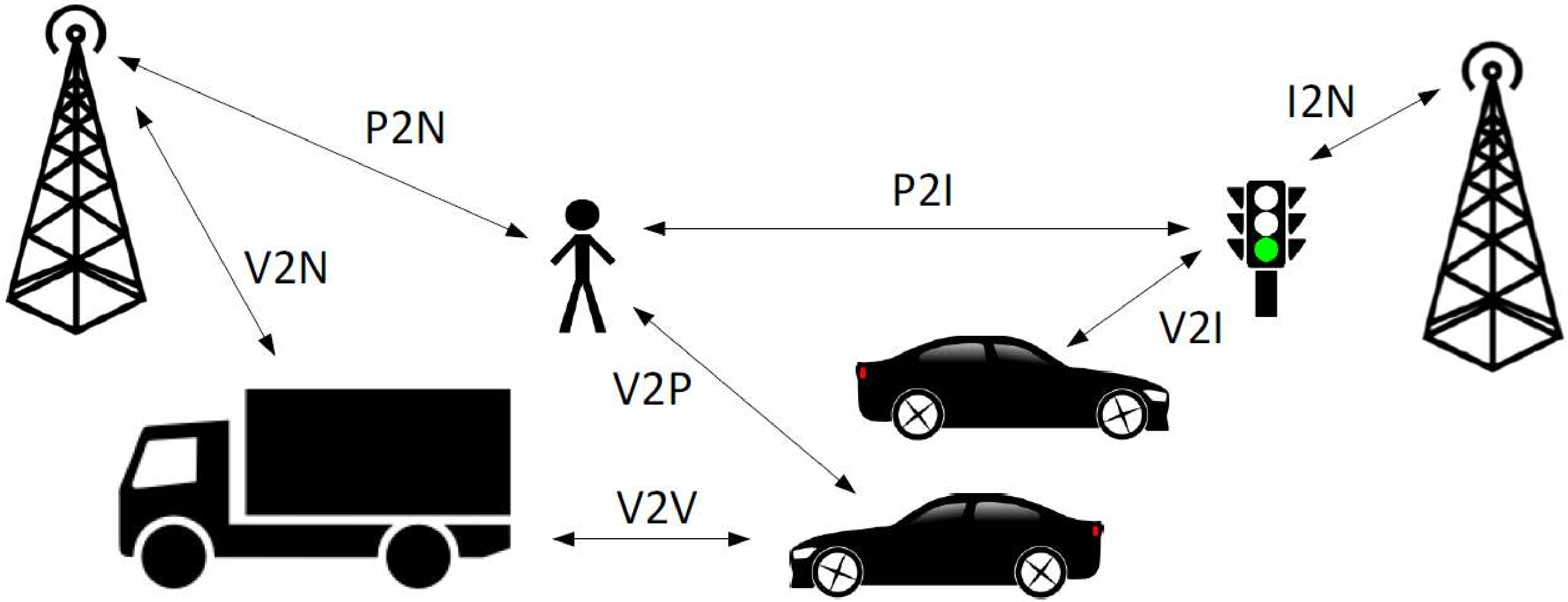
1. 차량통신 (V2X)

- V2B Vehicle to base station
- V2I Vehicle-to-Infrastructure
- V2P Vehicle to pedestrian
- V2V Vehicle-to-Vehicle
- V2R Vehicle to road side unit
- B2R Base station to road side unit
- P2B Pedestrian to base station
- P2P Pedestrian to pedestrian
- R2R Road side unit to road side unit
- RSU Road side unit



2. channel model 및 설명(common)

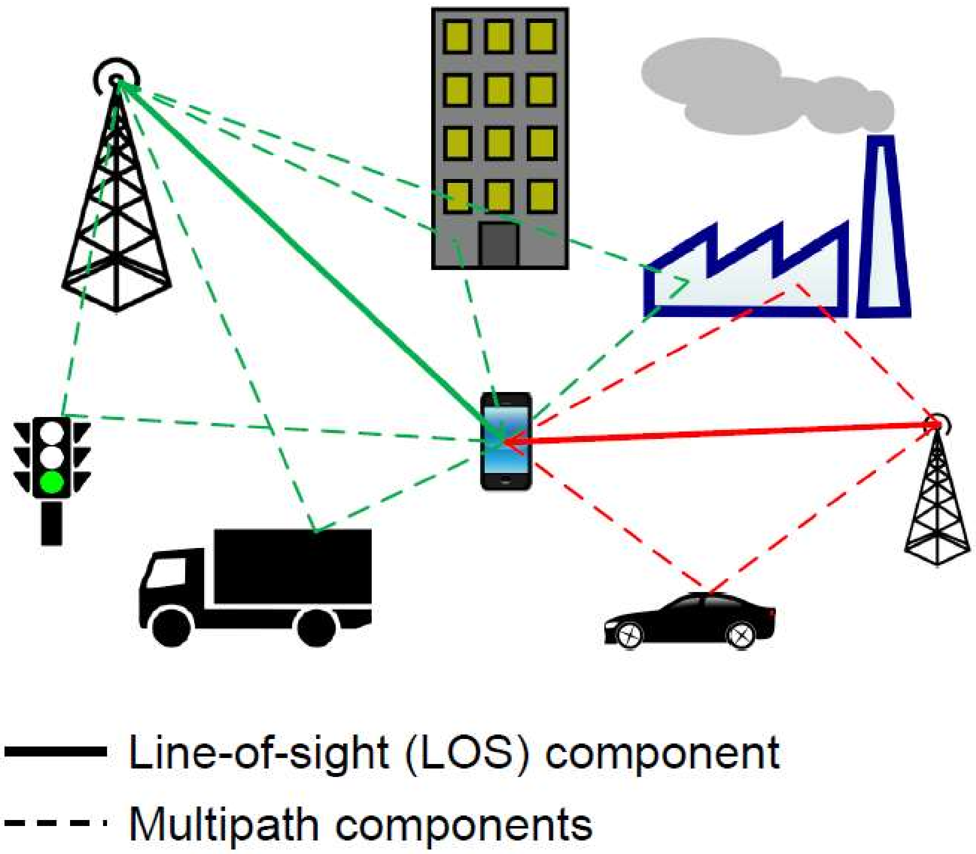
chnnel model	aspect of impairments	descripstion
Path Loss	path loss	attenuation based on TX-RX distance and carrier frequency.
statistical models	fading	add fading component (both small-scal and large-scale)
TDL	dopler effect	add Doppler effects due to speed differences between TX and RX.
GBSM	environment	modelling potential scatterers according to statistical distributions which affect MPCs.
GBDM	environment	whole propagation environment very scenario specific and computational expensive.

TDL(Tapped Delay Line), GBSM(Geomtry-based stochastic models)

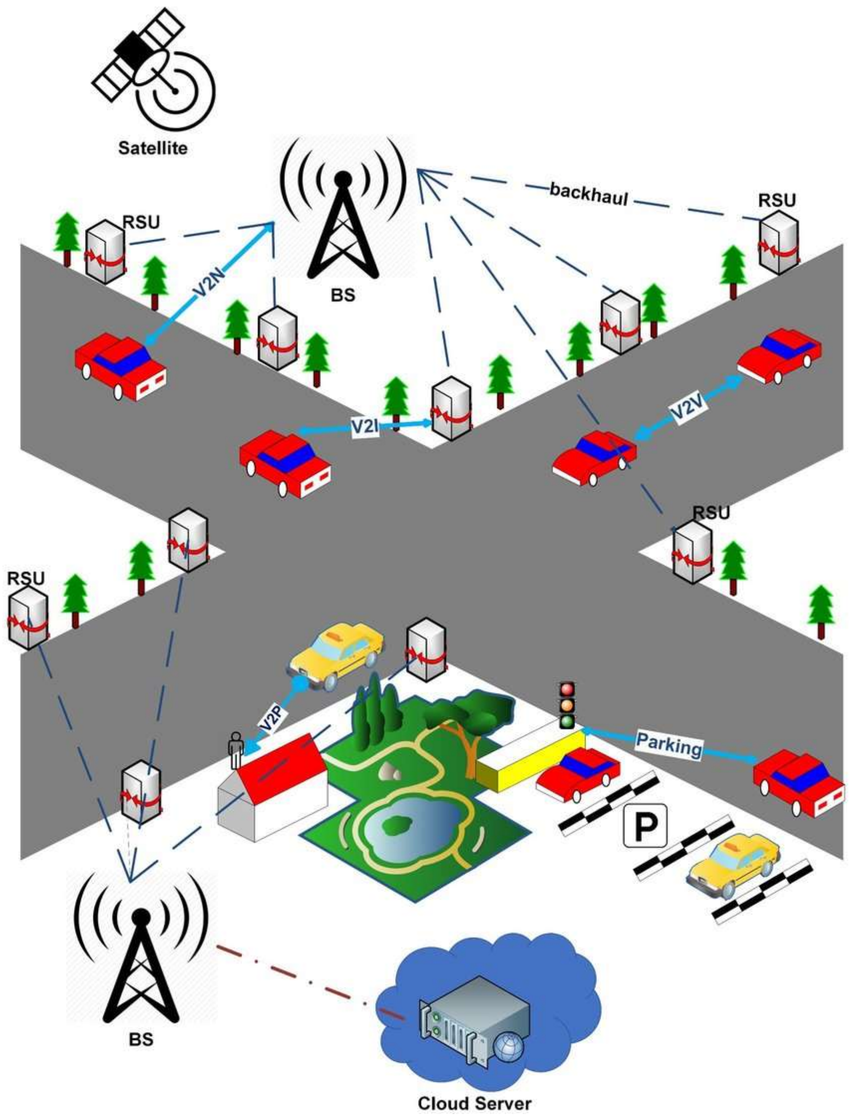
GBDM(Geometry-based deterministic models)

MPC(multipath component)

2. channel model 및 설명(common&V2X)



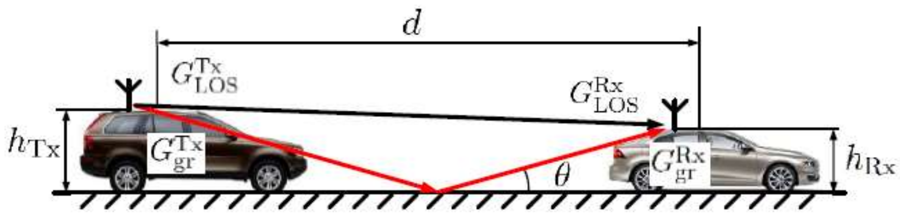
Typical comunication scenario



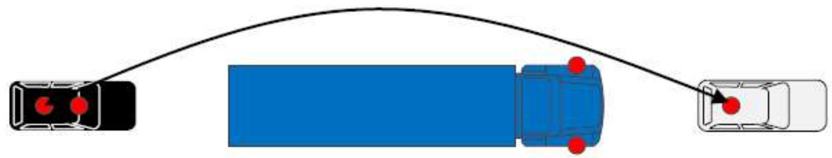
V2X scenario

2. channel model 및 설명(V2X)

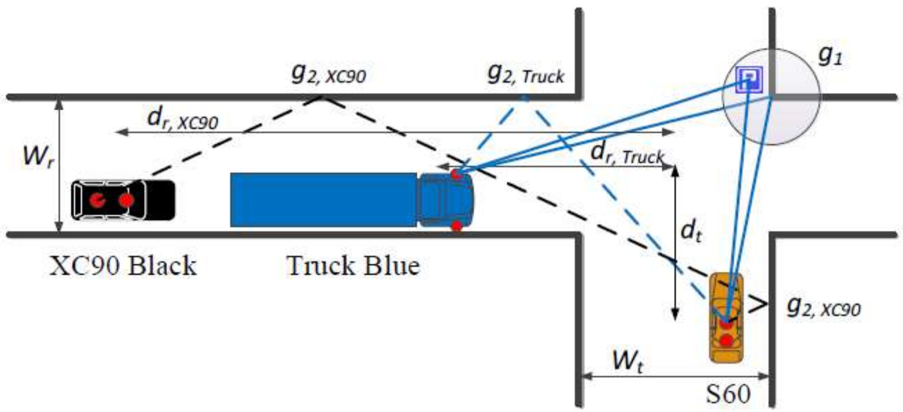
LOS: Line-Of-Sight



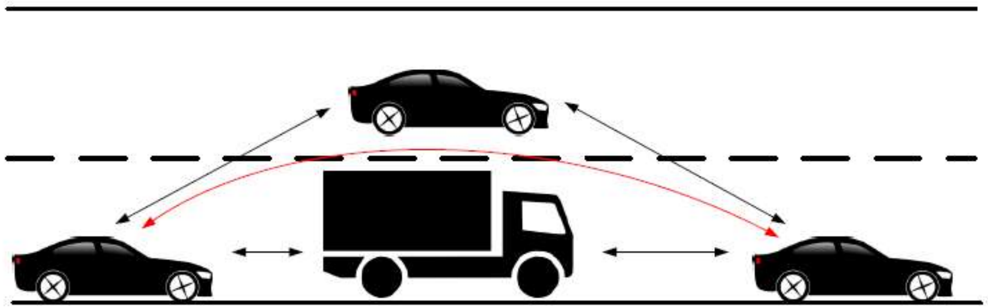
OLOS: Obstructed Line-Of-Sight



NLOS: Non Line-Of-Sight

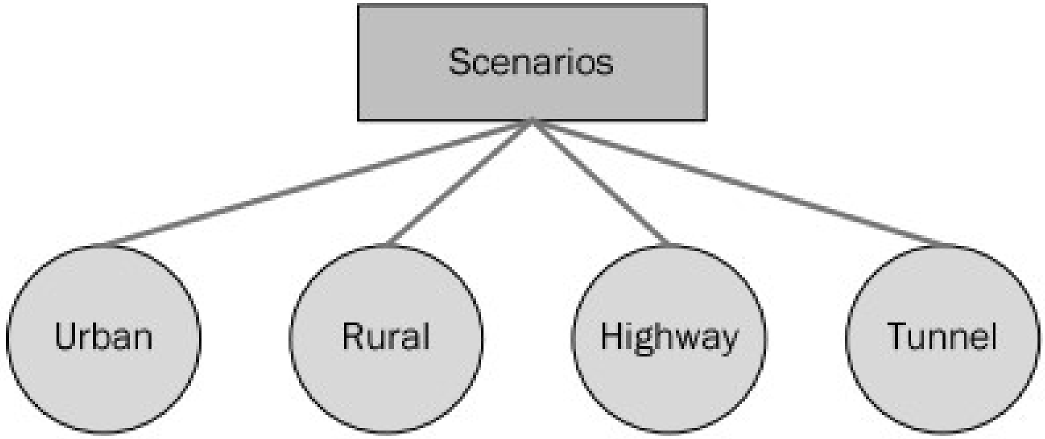


Multilink



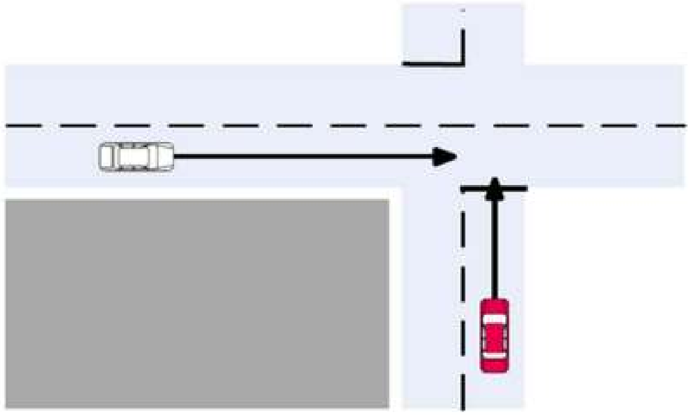
key point in V2V channel model

2. channel model 및 설명(V2X)

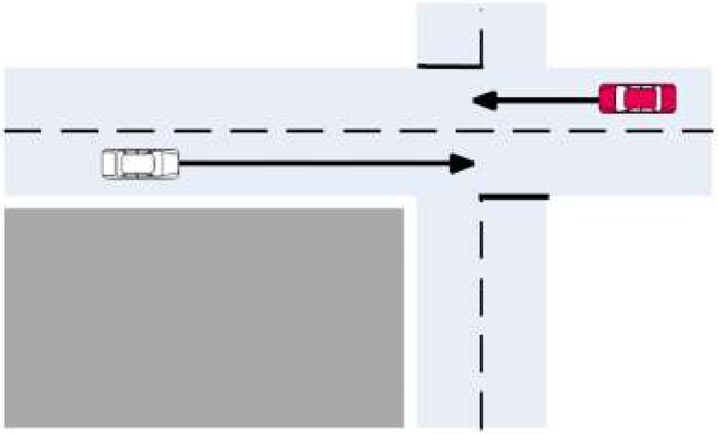


Urban	- single-lane or multi-lane city streets
Rural	- country road with open surroundings
Highway	- road with two(or more)lanes reserved usually for one-way traffic - maximum allowed driving speeds can vary between 120 km/h to 140 km/h
Tunnel	- two or more lanes that can be allocated for one-way - very rich scattering from the ground, walls, roof and metallic structure for the ventilation

2. channel model 및 설명(V2X)

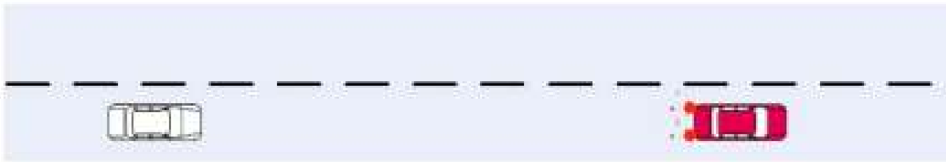


crossing scenario



approaching scenario

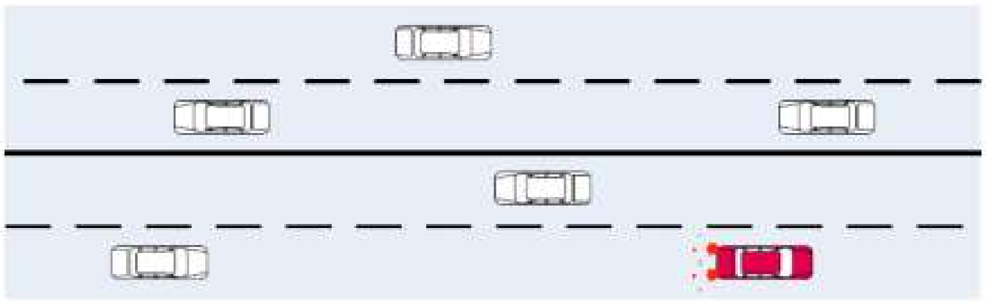
Urban



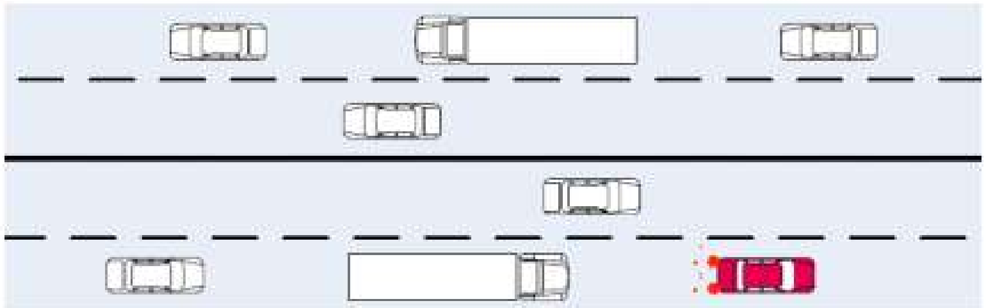
open environment with few scatterers

Rural

2. channel model 및 설명(V2X)



possible scatterers



LOS is obstructed

Highway

rich scattering

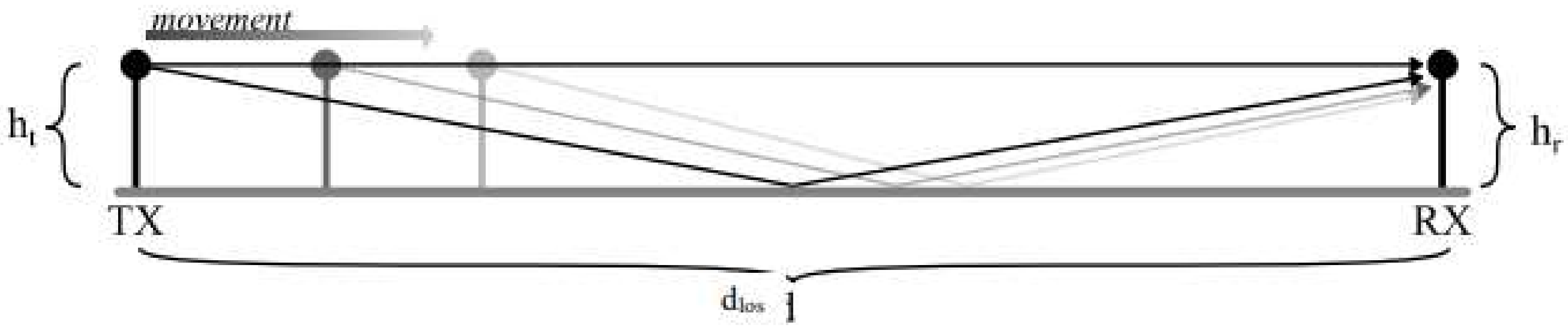
Tunnel

3. V2X pathloss model

1. Free space pathloss model(FSPL)

$$FSPL = 20\ log_{10}(d) + 20\ log_{10}(f) + 20 log_{10}\left(\frac{4\pi}{c}\right) - G_{Tx} - G_{Rx}$$

2. Two-way ground reflection model



$$E_{TOT} = E_{LOS} + E_{Ground} = \frac{E_0 d_0}{d_{LOS}} \cos\left[\omega_c\left(t - \frac{d_{LOS}}{c}\right)\right] + R_{Ground} \frac{E_0 d_0}{d_{ground}} \cos\left[\omega_c\left(t - \frac{d_{ground}}{c}\right)\right]$$

$$P_r = \frac{|E_{TOT}|^2 \lambda^2}{4\pi\eta}$$

3. V2X pathloss model

3. Log-distance path loss model

$$PL(d) = PL(d_0) + 10\,\gamma\,\log(d/d_0) + X_\sigma$$

PL : total path loss measured in decibel (dB)

PL(d0) : path loss at the reference distance d0

d : distance between TX and RX

γ : path loss exponent

Xσ : random shadowing effects

4. Received power

$$P_r = P_t + G_t + G_r - PL(d)$$

Pt : transmit power

Gt, Gr : antenna gains in dBi

3. V2X pathloss model

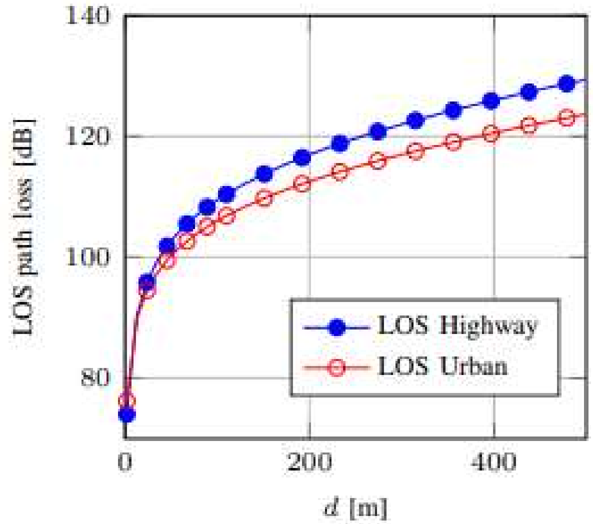
For V2V links at 5,9 GHz, NLOS

$$PL(d) = PL(d_0) + 10\,\gamma\,\log(d/d_0) + X_\sigma$$

	5GHz
d0	1m
PL(d0)	47
γ(slight obstruction by building)	2
γ(strong obstruction by building)	3
pathloss model	47+20log(d0)+X 47+30log(d0)+X

3. V2X pathloss model

LOS and NLOSv probabilities in highway and urban scenarios according to the 3GPP model



Path Loss Probability	Highway scenario		Urban scenario
	$d < 475$ m	$d > 475$ m	
$P_{\mathrm{LOS}}(d)$	$\min\{1, (2.1013 \cdot 10^{-6})d^2 - 0.002d + 1.0193\}$	$\max\{0, 0.54 - 0.001(d - 475)\}$	$\min\{1, 1.05e^{-0.0114d}\}$
$P_{\mathrm{NLOSv}}(d)$	$1 - P_{\mathrm{LOS}}(d)$		

(*) The NLOS status is derived from geometric considerations, which evaluate whether the direct path between the TX and the RX is blocked by static obstructions, e.g., buildings.

3GPP model(5G, 3GPP TR 37.885)

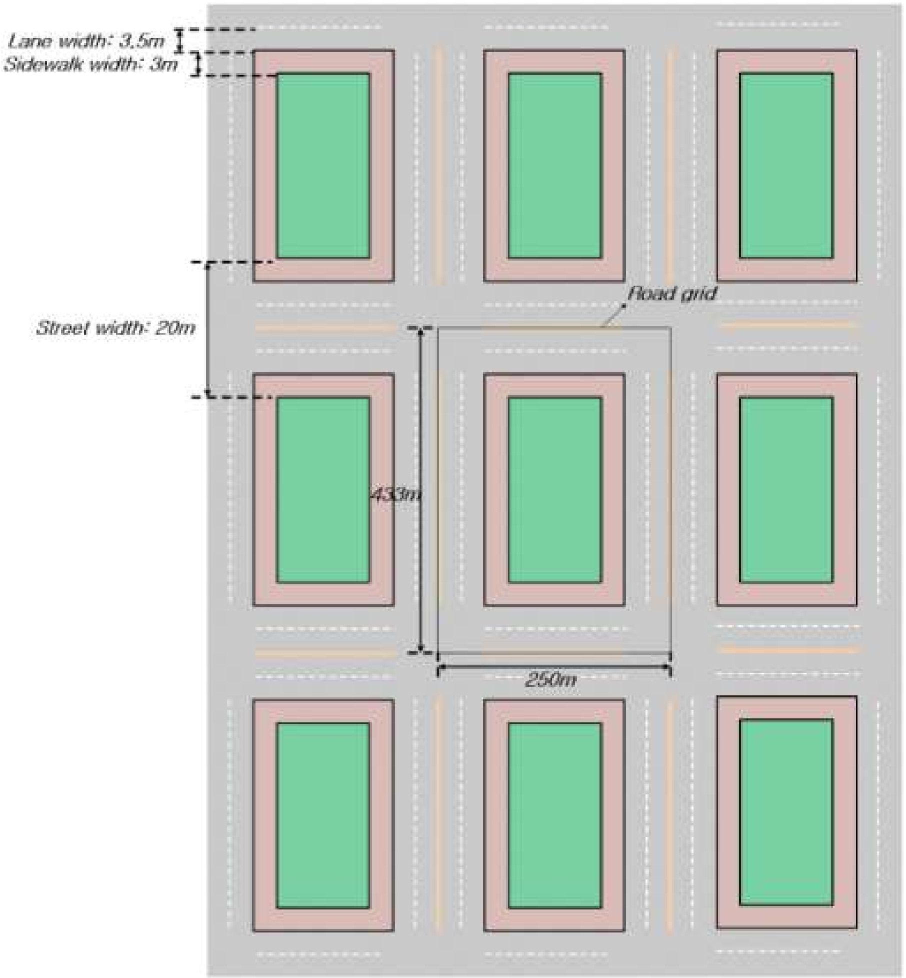
$$\begin{cases} \mathrm{PL}^{\mathrm{u}}_{\mathrm{LOS}}(d) = 38.77 + 16.7\log_{10}(d) + 18.2\log_{10}(f_c) + \chi_a \\ \mathrm{PL}^{\mathrm{h}}_{\mathrm{LOS}}(d) = 32.4 + 20\log_{10}(d) + 20\log_{10}(f_c) + \chi_a \end{cases}$$

3. V2X pathloss model

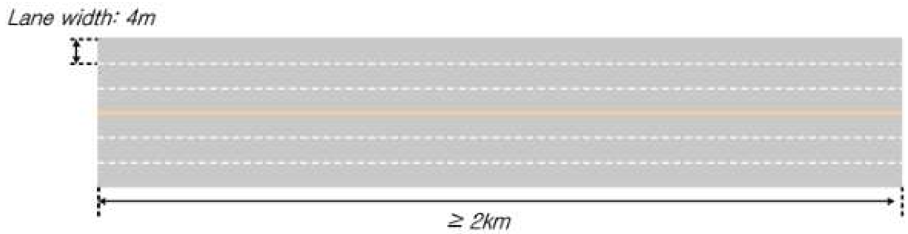
1. Road configuration for urban grid and highway

Parameter	Urban case	Highway case
Number of lanes	2 in each direction (4 lanes in total in each street)	3 in each direction (6 lanes in total in th e highway)
Lane width	3.5 m	4 m
Road grid size by the distance b etween intersections	433 m * 250 m. NOTE1	N/A
Simulation area size	Minimum 1299 m * 750 m NOTE2	Highway length >= 2000 m. Wrap arou nd should be applie d to the simulation area.
NOTE1: 3 m is reserved for sidewalk per direction (i.e., no vehicle or building in this reserved space). NOTE2: This value is tentative and could be modified after SA1'further input.		

3. V2X pathloss model



Road configuration for urban grid



Road configuration for highway grid

3. V2X pathloss model

2. Pathloss for V2V links

LOS/NLOS/NLOSv	Pathloss [dB]	Shadow fading std [dB][2]
LOS, NLOSv	For Highway case, $PL = 32.4 + 20\log_{10}(d_{3D}) + 20\log_{10}(f_c)$ For Urban case, $PL = 38.77 + 16.7\log_{10}(d_{3D}) + 18.2\log_{10}(f_c)$	$\sigma_{SF} = 3$
NLOS	$PL = 36.85 + 30\log_{10}(d_{3D}) + 18.9\log_{10}(f_c)$	$\sigma_{SF} = 4$
Note 1: f_c denotes the center frequency in GHz and d_{3D} denotes the Euclidean distance between TX and RX in 3D space in meters. Note 2: The model for spatial correlation of shadow fading defined in [13] applies.		

Pathloss equation of V2V is reused for that of V2P, P2P, V2R, R2R.

3. V2X pathloss model

3. Pathloss for V2B, P2B, B2R links

	Below 6 GHz		Above 6 GHz	
	LOS	NLOS	LOS	NLOS
V2B P2B B2R	Urban: TR 38.901 UMa LOS Highway: TR 38.901 RMa LOS	Urban: TR 38.901 UMa NLOS Highway: N/A	Urban: TR 38.901 UMa LOS Highway: TR 38.901 UMa LOS	Urban: TR 38.901 UMa NLOS Highway: N/A

TR(transmitter-receiver)

UMa(urban macro-cellular)

4. V2X pathloss model 그래프

```
%% SETTINGS
N = 256; %sample size
d = linspace(0,2000,N);
fc1 = 3*10^9;
fc2 = 28*10^9;
std_db_LOS = 3; std_db_NLOS = 4;

%% PATHLOSS (3GHz)
rng('shuffle');r = randn(1,N);
PL1 = 32.4+20*log10(d)+20*log10(fc1) + (r*std_db_LOS);
rng('shuffle');r = randn(1,N);
PL2 = 38.77+16.7*log10(d)+18.2*log10(fc1) + (r*std_db_LOS);
rng('shuffle');r = randn(1,N);
PL3 = 36.85+30*log10(d)+18.9*log10(fc1)+ (r*std_db_NLOS);
figure(1)
loglog(d,PL1,'b.',d,PL2,'r.',d,PL3,'g.');
title('pathloss, fc = 3GHZ');
xlabel('distance between Tx-Rx (m)');
ylabel('Pathloss(dB)');
legend('LOS highway', 'LOS urban','NLOS');

%% PATHLOSS (28GHz)
rng('shuffle');r = randn(1,N);
PL4 = 32.4+20*log10(d)+20*log10(fc2) + (r*std_db_LOS);
rng('shuffle');r = randn(1,N);
PL5 = 38.77+16.7*log10(d)+18.2*log10(fc2) + (r*std_db_LOS);
rng('shuffle');r = randn(1,N);
PL6 = 36.85+30*log10(d)+18.9*log10(fc2) + (r*std_db_NLOS);
figure(2)
loglog(d,PL4,'b.',d,PL5,'r.',d,PL6,'g.');
title('pathloss, fc = 28GHZ');
xlabel('distance between Tx-Rx (m)');
ylabel('Pathloss(dB)');
legend('LOS highway', 'LOS urban','NLOS');
```

matlab code

sample nuber = 256

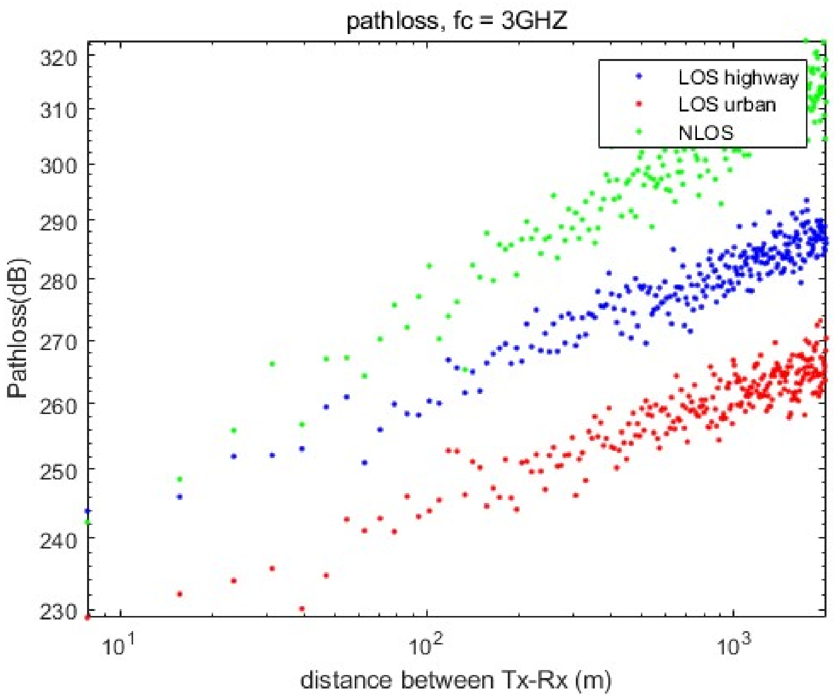
LOS(Highway/Urban) (dB)

d	fc = 3GHz	fc = 28GHz
1	221 / 211	241 / 229
10	241 / 227	261 / 246
100	262 / 245	281 / 262
1000	282 / 261	301/279

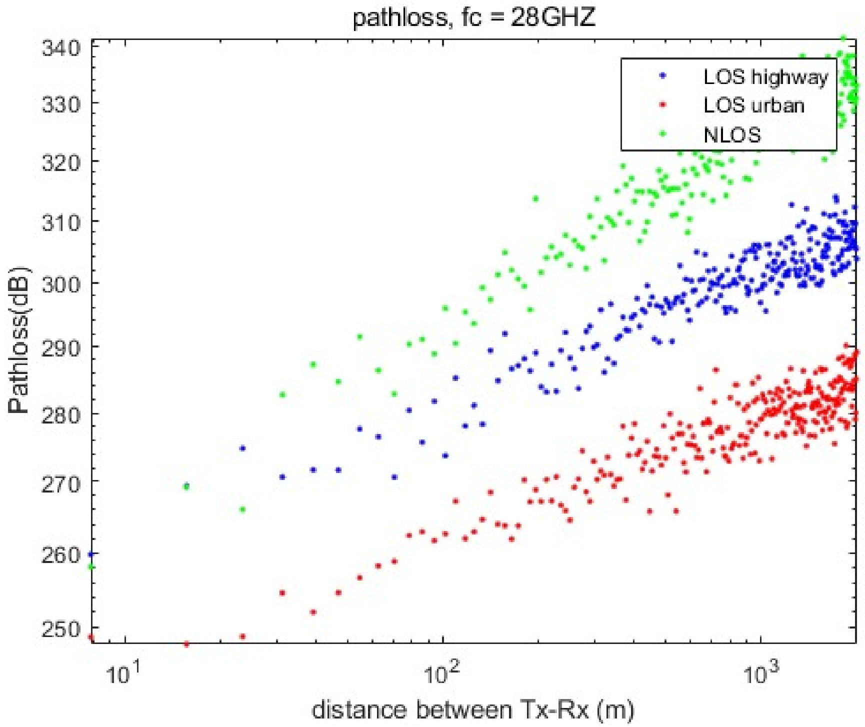
NLOS (dB)

d	fc = 3GHz	fc = 28GHz
1	216	234
10	246	264
100	276	294
1000	306	324

4. V2X pathloss model 그래프



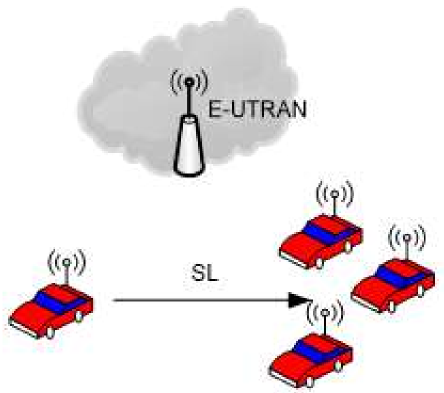
3GHz



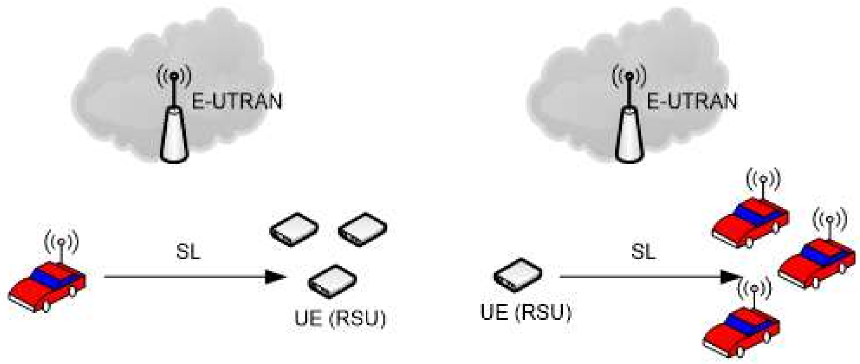
28GHz

5. LTE(4G), NR(5G) 차량통신 path loss model 비교

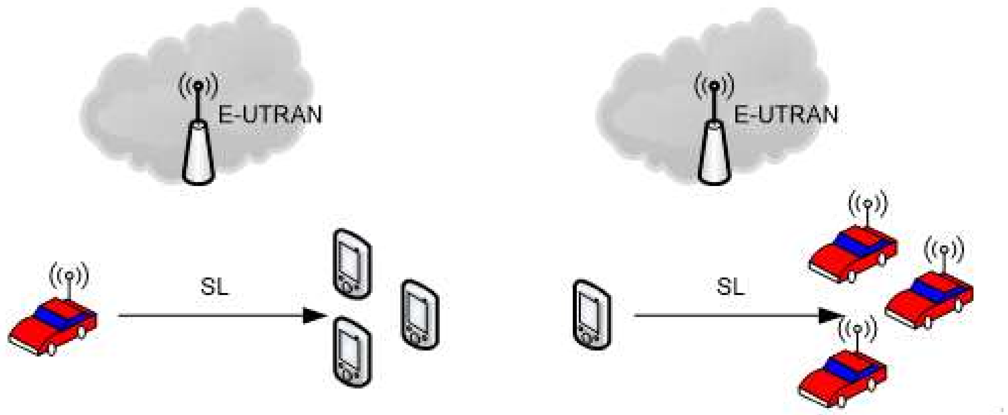
- 3GPP 36.885 Study on LTE-based V2X services



V2V operation



V2I operation



V2P operation

5. LTE(4G), NR(5G) 차량통신 path loss model 비교

- Details of vehicle UE drop and mobility model(LTE)

Parameter	Urban case	Highway case
Number of lanes	2 in each direction (4 lanes in total in each street)	3 in each direction (6 lanes in total in th e highway)
Lane width	3.5 m	4 m
Road grid size by the distance bet ween intersections	433 m * 250 m. NOTE1	N/A
Simulation area size	Minimum 1299 m * 750 m NOTE2	Highway length >= 2 000 m. Wrap around should be applied to the simulation area.
Vehicle density	**Average inter-vehicle distance in the same lane is 2.5sec absolute cehicle speed. Baseline : The same density/speed in all the lanes in one simulation**	
Absolute vehicle speed	**15km/h, 60km/h**	**140km/h, 70km/h**

5. LTE(4G), NR(5G) 차량통신 path loss model 비교

Pathloss model(LTE, 3GPP TR 36.885)

	Urban case	Freeway case
assumption 6GHz	WINNER2 antenna(up to 6GHz) Pathloss at 3m is used if the distance is less than 3m	WINNER2 antenna(up to 6GHz) Pathloss at 3m is used if the distance is less than 3m
pathloss[dB]	128.1+37.6log10(R), R in kilometers, σ_{SF} = 8dB	

Pathloss model(NR, 3GPP TR 37.885)

LOS/NLOS/NLOSv	Pathloss [dB]	Shadow fading std [dB][2]
LOS, NLOSv fc = 6GHz	For Highway case, PL = 168.0 + 20 $\log_{10}$(R), R in km For Urban case, PL=166.6 + 16.7 $\log_{10}$(R), R in km	σ_{SF} = 3

6. Ref

1. 3GPP TR 36.885
2. 3GPP TR 37.885
3. 3GPP TR 38.901
4. ETSI TR 103 257-1
5. M. Giordani, T. Shimizu, A. Zanella, T. Higuchi, O. Altintas and M. Zorzi, "Path Loss Models for V2V mmWave Communication: Performance Evaluation and Open Challenges," 2019 IEEE 2nd Connected and Automated Vehicles Symposium (CAVS), Honolulu, HI, USA, 2019, pp. 1-5, doi: 10.1109/CAVS.2019.8887792.