Simulation assumptions and simulation results of LLS and SLS

1 THE LINK LEVEL SIMULATION

1.1 Simulation assumptions

The link level simulation assumptions are applied as follows:

- For fast fading model in V2V link:
    - Channel model in Section A.2.1.2.1.2 in 3GPP TR 36.843 is used.
    - NLOS and LOS link level simulation results should be provided with absolute speed 15 and 60 km/h respectively, and only LOS link level simulation results should be provided with absolute speed 140 and 250 km/h.
- Message sizes:
    - Size of app layer: 190, 300 bytes
    - Take link layer overhead into account:
        - LTE-V2X: +16 bytes [MAC (10 bytes) / RLC (1 byte) / PDCP (5 bytes)]
        - DSRC: + 38 bytes [MAC (30 bytes) / LLC(8 bytes)]
- Modulation & coding rate:
    - Comparison 1:
        - LTE-V2X: QPSK, 1 transmission w/o segmentation, 1/2 coding rate
        - DSRC: QPSK, 1/2 coding rate (i.e. 6Mbps)
    - Comparison 2:
        - LTE-V2X: QPSK, 2 transmission w/o segmentation, 1/2 coding rate for each transmission
        - DSRC: BPSK, 1/2 coding rate (i.e. 3Mbps)
- Carrier frequency:
    - 5.9GHz
- Absolute speed:
    - 15,60,140,250km/h
- Relative vehicle speed:
    - 30,120,280,500km/h
- Frequency error:
    - Baseline is to evaluate both Case 1 and Case 2.
        - Case 1: The extreme case should be assumed, i.e., frequency error between TX and RX is fixed as X PPM.
            - X = 0.3 for LTE-V2X
            - X = 40 for DSRC
        - Case 2: Frequency error in each UE is uniformly distributed [-Y, Y] PPM w.r.t. UE's sync reference.
            - Y = 0.1 for LTE-V2X
            - Y = 20 for DSRC

- Companies should describe the receiver algorithm of the evaluated options.
- Time synchronization
  - ideal time synch for both LTE-V2X and DSRC
- Number of antennas
  - 1 TX and 2 RX antennas for both LTE-V2X and DSRC. Baseline is that 2 RX antennas are separated by wavelength/2.
- Performance metric
  BLER vs SNR

1.2 Simulation results

The link level simulation results are summarized in Table 1 and Table 2.

Table 1 Comparison of SNR between LTE-V2X and DSRC (BLER=0.1)

BLER=0.1	MCS comparison 1: DSRC_SNR minus LTE-V2X_SNR (dB)				MCS comparison 2: DSRC_SNR minus LTE-V2X_SNR (dB)				Link level simulation results range (dB)
Scenarios	190bytes/ fixed CFO	300bytes/ fixed CFO	190bytes/ rand CFO	300bytes/ rand CFO	190bytes/ fixed CFO	300bytes/ fixed CFO	190bytes/ rand CFO	300bytes/ rand CFO	
30kmh/LOS	4.2	4.7	4.3	4.8	4.4	4.9	4.2	4.9	[4.2, 5.2]
120kmh/LOS	4.7	5.0	4.6	5.0	4.6	5.1	4.6	5.2	
280kmh/LOS	4.6	4.7	4.5	4.8	4.4	4.9	4.5	4.9	
500kmh/LOS	2.5	2.5	2.3	2.6	3.1	3.7	3.2	3.7	[2.3, 3.7]
30kmh/NLOS	1.0	2.3	1.3	1.3	0.5	1.4	0.5	1.4	[0.5, 2.8]
120kmh/NLOS	2.1	2.7	2.1	2.8	1.6	2.2	1.5	2.3	

Table 2 Comparison of Receiving Power between LTE-V2X and DSRC (BLER=0.1)

BLER=0.1	MCS comparison 1: DSRC_RX_Power minus LTE-V2X_RX_Power (dB)				MCS comparison 2: DSRC_RX_Power minus LTE-V2X_RX_Power (dB)				Link level simulation results range (dB)
Scenarios	190bytes/ fixed CFO	300bytes/ fixed CFO	190bytes/ rand CFO	300bytes/ rand CFO	190bytes/ fixed CFO	300bytes/ fixed CFO	190bytes/ rand CFO	300bytes/ rand CFO	
30kmh/LOS	10.2	8.9	10.3	9.1	10.3	9.1	10.1	9.1	[8.9, 10.7]
120kmh/LOS	10.7	9.1	10.6	9.2	10.6	9.4	10.6	9.4	
280kmh/LOS	10.6	8.9	10.5	9.0	10.4	9.1	10.5	9.1	
500kmh/LOS	8.5	6.6	8.3	6.8	9.1	8.0	9.2	7.9	[6.6, 9.2]
30kmh/NLOS	7.0	6.5	7.3	5.5	6.5	5.6	6.5	5.7	[5.5, 8.1]
120kmh/NLOS	8.1	6.9	8.1	7.0	7.6	6.4	7.4	6.6	

Based on the link level simulation results, the link level performance of LTE-V2X is improved with the following reasons:

- ✓ 4-column DMRS can improve the performance in the high Doppler case;
- ✓ Turbo code gain.
- ✓ Because FDM mechanism is utilized in LTE-V2X, the resource in frequency domain is part of the whole bandwidth (sub-channel), but the resource in frequency domain of DSRC is whole bandwidth. With the assumption of same noise figure, the noise has less impact on LTE-V2X than DSRC.

2 THE SYSTEM LEVEL SIMULATION

2.1 Simulation assumptions

The following system level simulation assumptions are presented:

1) Evaluation scenarios

The two vehicle UE dropping cases are defined: Urban case and Freeway case. Details of evaluation scenarios are in Table 3.

Table 3: Details of evaluation scenarios

Parameter		Assumption
Carrier frequency		- PC5 based V2V& DSRC: 5.9 GHz
Bandwidth		- PC5 based V2V & DSRC: 10 MHz
Number of carriers		One carrier is baseline.
Synchronization		Frequency error should be considered. Baseline is to evaluate both Case 1 and Case 2 defined in section 2.1. Ideal time synch for both LTE-V2X and DSRC.
Vehicle UE , UE type RSU, Pedestrian UE parameters	In-band emission	In-band emission model in Section A.2.1.5 in 3GPP TR 36.843 is reused with {W, X, Y, Z} = {3, 6, 3, 3} for single cluster SC-FDMA. (only for LTE-V2X)
	Antenna height	1.5 m for vehicle UE
	Antenna pattern	Omni 2D
	Antenna gain	3 dBi for vehicle UE
	Maximum transmit power	23 dBm
	Number of antennas	1 TX and 2 RX antennas for both LTE-V2X and DSRC. Baseline is that 2 RX antennas are separated by wavelength/2.
	Noise figure	9 dB

2) UE drop and mobility model

Vehicle UEs are dropped on the roads according to spatial Poisson process. The vehicle density is determined by the assumption on the vehicle speed, and the vehicle location should be updated every 100 ms in the simulation.

In Urban case, a vehicle changes its direction at the intersection as follows:

- Go straight with probability 0.5
- Turn left with probability 0.25
- Turn right with probability 0.25

Details of vehicle UE drop and mobility model for each of Urban and Freeway cases are in Table 4. Figures 1 and Figure 2 illustrate the road configuration of the two cases.

Table 4: Details of vehicle UE drop and mobility model

Parameter	Urban case	Freeway case
Number of lanes	2 in each direction (4 lanes in total in each street)	3 in each direction (6 lanes in total in the freeway)
Lane width	3.5 m	4 m
Road grid size by the distance between intersections	433 m * 250 m. Note that 3 m is reserved for sidewalk per direction (i.e., no vehicle or building in this reserved space)	N/A
Simulation area size	Minimum [1299 m * 750 m]	Freeway length >= 2000 m. Wrap around should be applied to the simulation area.
Vehicle density	Average inter-vehicle distance in the same lane is 2.5 (baseline) or 4sec * absolute vehicle speed. Baseline: The same density/speed in all the lanes in one simulation.	
Absolute vehicle speed	15 km/h, 60 km/h	140 km/h, 70 km/h

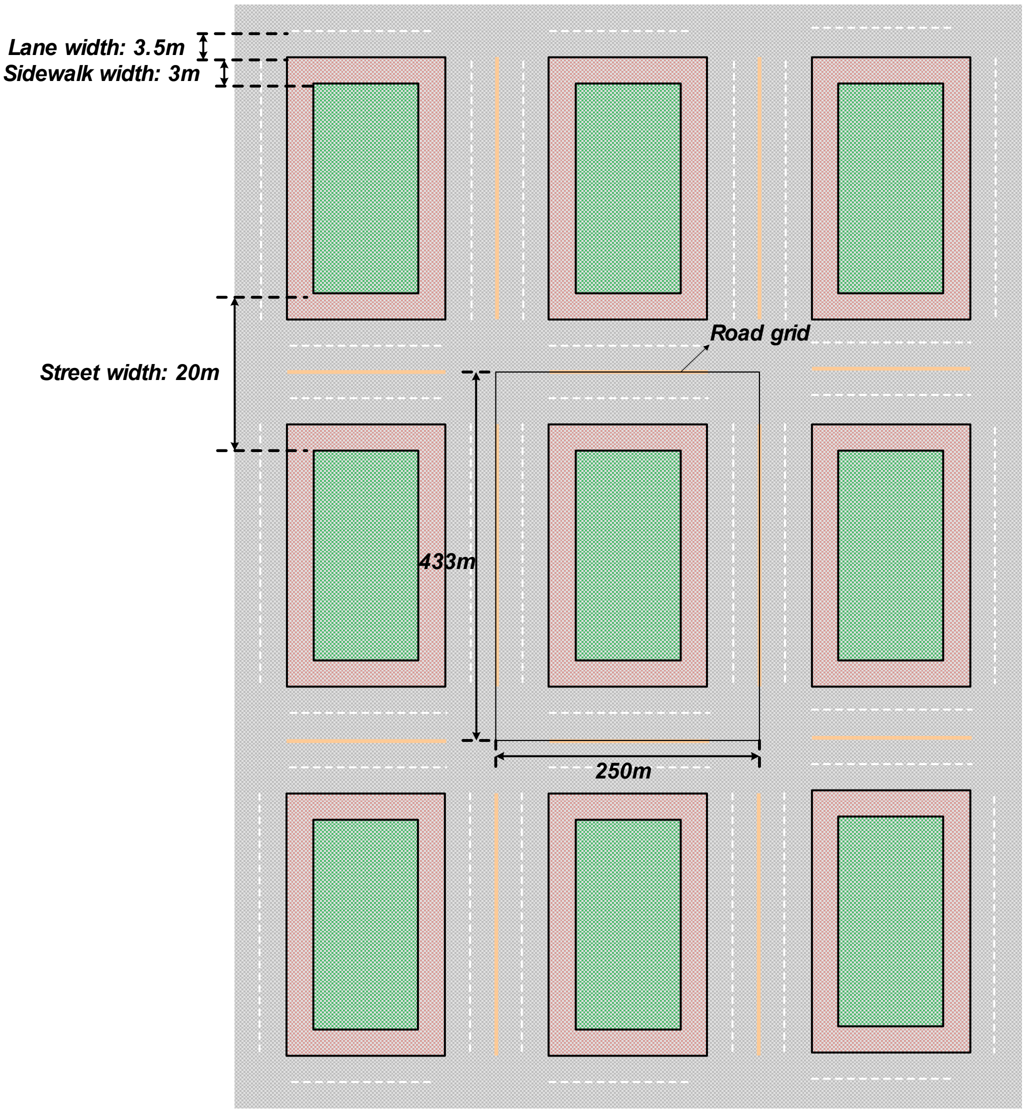

Figure 1: Road configuration for Urban case

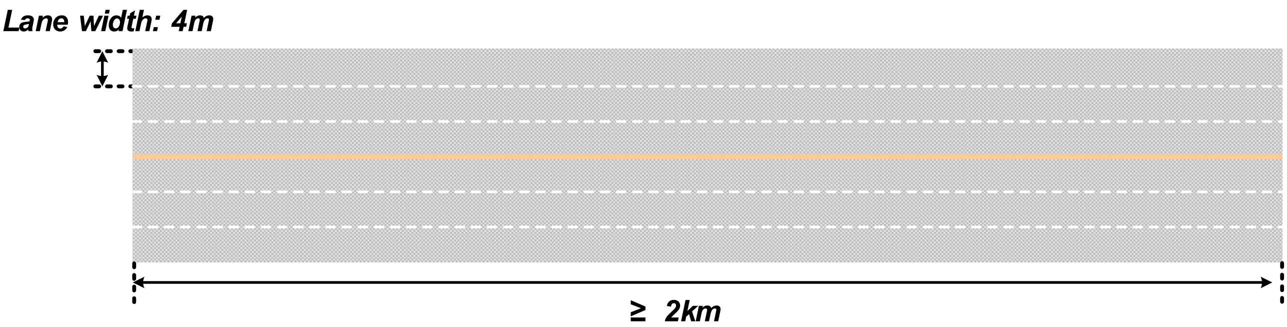

Figure 2: Road configuration for Freeway case

3) Channel model

Assumptions for channel between two vehicle UEs are in Table 5.

Table 5: Assumptions for vehicle-to-vehicle channel

Parameter	Urban case	Freeway case
Pathloss model	WINNER+ B1 Manhattan grid layout (note that the antenna height should be set to 1.5 m.). Pathloss at 3 m is used if the distance is less than 3 m.	LOS in WINNER+ B1 (note that the antenna height should be set to 1.5 m.). Pathloss at 3 m is used if the distance is less than 3 m.
Shadowing distribution	Log-normal	Log-normal
Shadowing standard deviation	3 dB for LOS and 4 dB for NLOS	3 dB
Decorrelation distance	10 m	25 m
Fast fading	NLOS in Section A.2.1.2.1.1 or A.2.1.2.1.2 in 3GPP TR 36.843 with fixed large scale parameters during the simulation.	

Vehicle-to-vehicle channels are updated during the simulation as follows:

- Let N be the number of vehicle UE in system simulation
- Initialization (at time 0)
  - N vehicle locations are generated per agreed drop model
  - PL (0) – NxN matrix generated as per vehicle locations and agreed channel m odels
  - Shadowing (in log domain): S(0) – NxN i.i.d. (with the exception that shadowin g between two vehicles should be the same in the two directions) normal mat rix generated as per agreed shadowing model
  - Fading (0) – NxN i.i.d. processes with a common distribution
- Update (at time 100*n ms)
  - Vehicle locations are updated as per agreed update rules
  - PL(n) – N x N matrix generated as per updated vehicle locations
  - S(n) = exp(-D/D_corr) .* S(n-1) +sqrt{ (1-exp(-2*D/D_corr))}.*N_S(n)
    - where N_S(n) is an NxN i.i.d. (with the exception that shadowing b etween two vehicles should be the same in the two directions) normal matrix generated as per the agreed shadowing model
    - D is the update distance matrix where D(i,j) is change in distance of l ink i to j from time n-1 to time n
  - Fading process is not impacted due to vehicle location updates – fading is onl y updated due to time
  - UE performance should reflect fast fading variation within the subframe

4) Traffic model

- Traffic model for V2V

There are two traffic models used in evaluation: Periodic traffic case and Event-triggered traffic case. Periodic traffic case is mandatory. Event-triggered traffic case can be evaluated optionally with or without Periodic traffic.
Every vehicle in the simulation generates messages according to the traffic model.
For Periodic traffic, message generation periods are defined in the following 5 distinctive scenarios in Table 6.

Table 6: Message generation period for Periodic traffic

Index	Vehicle dropping scenarios	Absolute vehicle speed (km/h)	Message generation period (ms)
1	Freeway	140	100
2	Freeway	70	100
3	Urban	60	100
4	Urban	15	100
5	Urban	15	500

For Periodic traffic, working assumption of application layer message size is that one 300-byte message followed by four 190-byte messages, and the time instance of 300-byte size message generation is randomized among vehicles. Note that it is allowed not to consider message size in calculating the performance metric.
For Event-triggered traffic, event arrival follows Poisson process with the arrival rate X (up to company choice) per second for each vehicle. Once event triggered, 6 messages are generated with space of 100ms. Working assumption of application layer message size for Event-trigger traffic at L1 is 800bytes.

For each application layer message, the following additional link layer overhead may or need not be taken into account in the evaluation. Other overhead values are not precluded:

- LTE-V2X: +16 bytes [MAC (10 bytes) / RLC (1 byte) / PDCP (5 bytes)]
- DSRC: + 38 bytes [MAC (30 bytes) / LLC(8 bytes)]

5) Performance metric

- Reliability & Communication range

For evaluation of proposed schemes for V2V, the following metric(s) shall be considered.

- Packet Reception Ratio (PRR) :

- For one Tx packet, the PRR is calculated by X/Y, where Y is the number of UE/vehicles that located in the range (a, b) from the TX, and X is the number of UE/vehicles with successful reception among Y. CDF of PRR and the following average PRR are used in evaluation
  - CDF of PRR with a = 0, b = baseline of 320 meters for freeway and 150 meters for urban. Optionally, b = 50 meters for urban with 15 km/h vehicle speed.
  - Average PRR, calculated as (X1+X2+X3….+Xn)/(Y1+Y2+Y3…+Yn) where n denotes the number of generated messages in simulation. with a = i*20 meters, b = (i+1)*20 meters for i=0, 1, …, 25

2.2 Simulation results

The system level simulation results are summarized in the following Table 7 and Table 8.

Table 7. Comparison Table of SLS Results (Urban)

Urban						
Speed	Company	PRR	3GPP LTE-V2X (distance in m)	IEEE 802.11p (distance in m)	Gain (in m)	Gain (in %)
15 km/h	Ericsson	95%	61	42	19	45%
		90%	77	55	22	40%
		80%	98	71	27	38%
60 km/h	Datang	95%	64	38	26	68%
		90%	80	60	20	33%
		80%	98	81	17	21%
	Huawei	95%	67	40	27	68%
		90%	82	60	22	37%
		80%	100	75	25	33%
	LG	95%	66	43	23	53%
		90%	84	59	25	42%
		80%	106	80	26	33%
	Average 60 km/h Urban	95%	66	40	25	63%
		90%	82	59	22	37%
		80%	101	78	22	29%

Table 8. Comparison Table of SLS Results (Freeway)

Freeway						
Speed	Company	PRR	3GPP LTE-V2X (distance in m)	IEEE 802.11p (distance in m)	Gain (in m)	Gain (in %)
70 km/h	Datang	95%	160	142	18	13%

		90%	210	170	40	24%
		80%	248	221	27	12%
	Huawei	95%	112	95	17	18%
		90%	167	142	25	18%
		80%	241	179	62	35%
	LG	95%	127	106	21	20%
		90%	182	152	30	20%
		80%	277	186	91	49%
	Average 70 km/h freeway	95%	133	114	19	16%
		90%	186	155	32	20%
		80%	255	195	60	31%
140 km/h	Datang	95%	306	167	139	83%
		90%	360	210	150	71%
		80%	410	222	188	85%
	Ericsson	95%	261	157	104	66%
		90%	343	192	151	79%
		80%	423	222	201	91%
	Huawei	95%	220	135	85	63%
		90%	309	170	139	82%
		80%	392	191	201	105%
	LG	95%	199	151	48	32%
		90%	305	177	128	72%
		80%	405	201	204	101%
	Average 140 km/h freeway	95%	247	153	94	62%
		90%	329	187	142	76%
		80%	408	209	199	95%