Opportunistic Vehicular Networks by Satellite Links for Safety Applications

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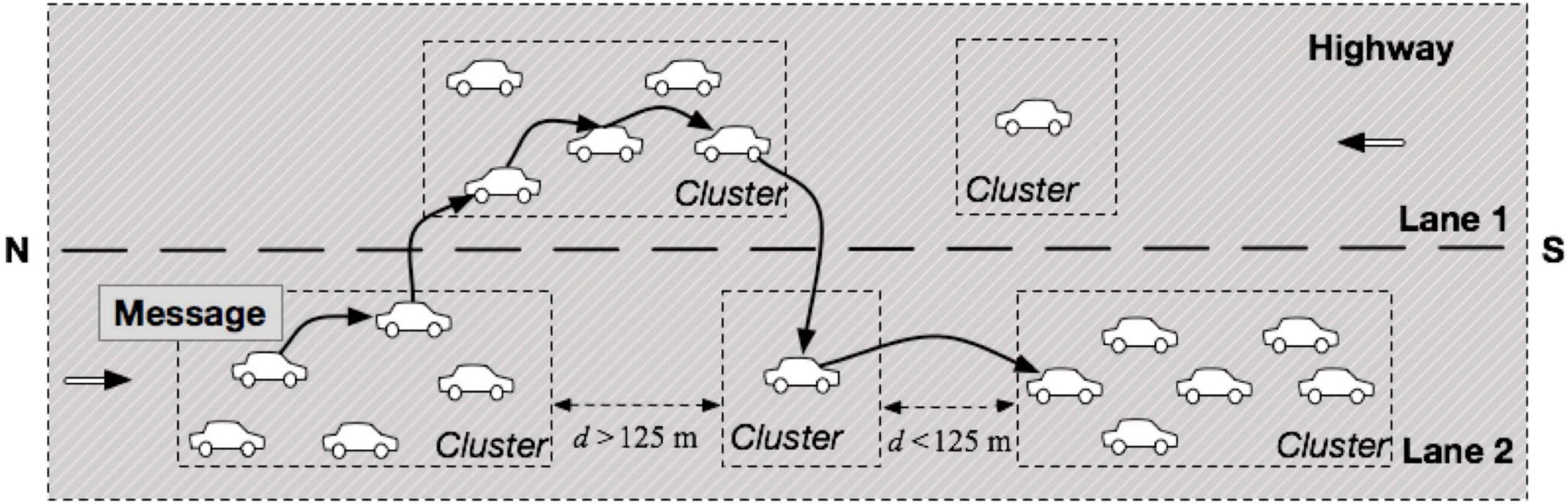
Outline

- **Opportunistic Networking** as traditional connectivity in VANETs.
  - Limitation of vehicular communications due to different kinds of traffic density.
- **Emergency scenarios**
  1. Isolated vehicles need help;
  2. No connectivity (no wireless and cellular networks, no V2V communications)
- Introduction of **Satellite links** in VANETs for safety applications.

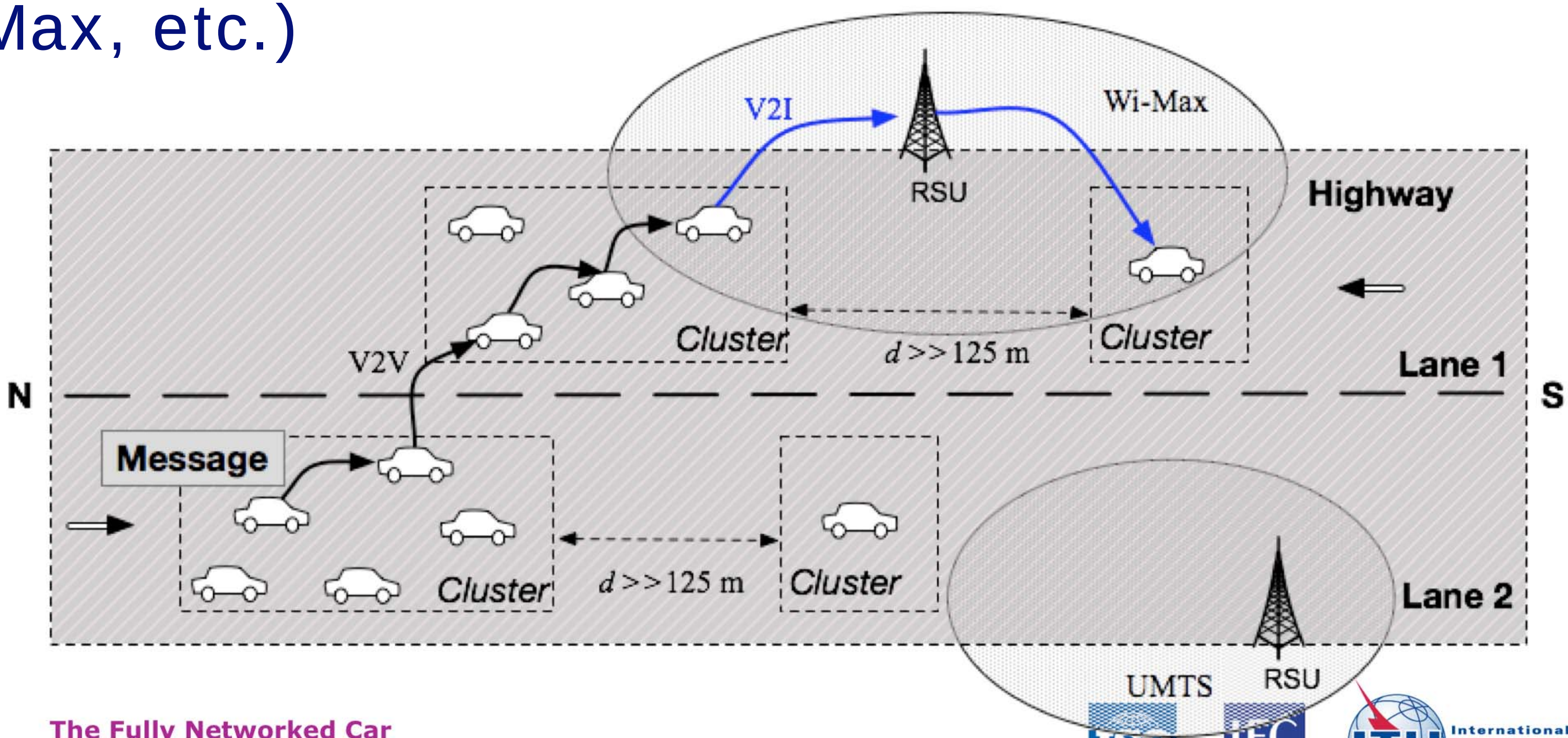
Opportunistic Networking in VANETs

- In *dense* or *sparse* traffic scenarios, vehicular communications are available when minimum distance between vehicles is assured.
- *Bridging* techniques exploit temporally connections in order to flood information messages.



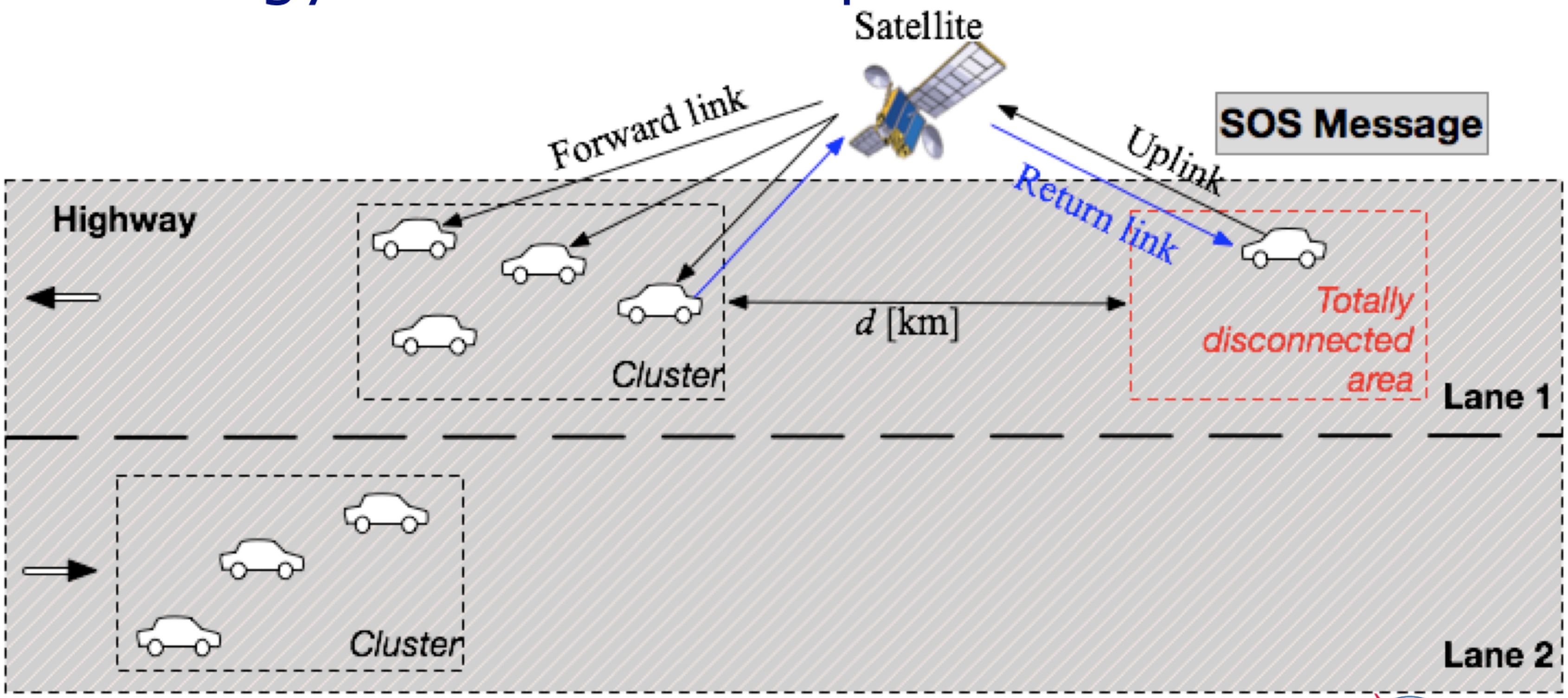
Opportunistic Networking in VANETs

- Preexistent network infrastructure should be exploit when available, and if vehicles are necessary equipped with several Network Interface Cards (NICs) (*i.e.* UMTS/HSDPA/LTE, Wi-Fi, Wi-Max, etc.)



Satellite Connectivity in VANETs

- In *totally-disconnected* scenarios, vehicular communications are not available.
- Satellite connectivity should represent the only technology in order to keep a vehicle connected.



Why Satellites in VANETs? (1/2)

- **Strength points**:
  1. Global connectivity;
  2. Broadcast and multicast services;
  3. Satellite is more robust than terrestrial infrastructure (e.g. natural/man-made disasters).

- **Weakness points**:
  1. Propagation channel for land mobile scenarios (multipath, shadowing and blockage);
  2. Size and form factor of *on-board* antennas in some cases unacceptable compared to terrestrial solutions;
  3. Challenging link budget

Why Satellites in VANETs? (2/2)

- **Benefits**:
  1. Usage reduction of terrestrial network infrastructure;
  2. Usage reduction of DSRC multi-hops;
  3. Service coverage extension w.r.t. terrestrial infrastructure.

- Our technique is intended to augment ***medium-range*** communication to bridge isolated vehicles, or clusters of vehicles / ground facilities, when no other mechanism is available.

Satellite link: orbit considerations

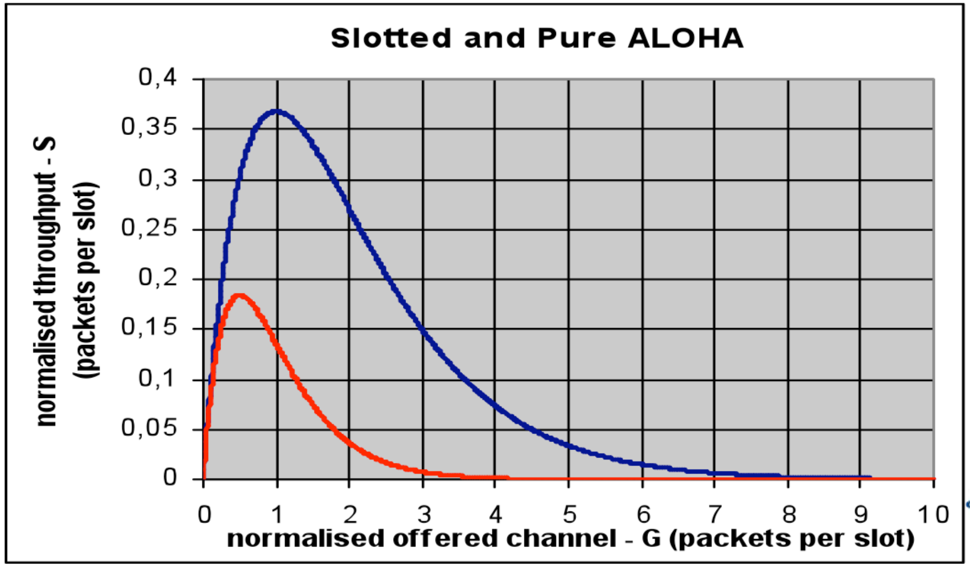
Orbit type		Orbit height [Km] / inclination [°]	Coverage	Application
HEO		(548 – 39957) / 64	High latitude (polar) regions for large fraction of the orbital period	• Communication with mobiles in presence of masking angle for low elevation angles
Circular	LEO	(800 – 2000) / (80-100)	Satellite passing over every region of the earth (15 – 20 satellites)	• Observation, store-and-forward communications. • Several tens of satellites for worldwide real-time communications
Circular	MEO	(10000 – 26000) / (40 -60)	Continuous (10-15 satellites)	• Real-time world-wide communications.
Circular	GEO	35786 / 0	No polar regions	• Radio relay in real time

Satellite link: access to satellite

- The choice of access type depends above all on economic considerations; it depends also on the volume and type of traffic

Type of traffic	Type of access
Long messages implying continuous or quasi-continuous transmission of a carrier	FDMA, TDMA, CDMA
Short messages, random generation, long dead time between messages	Random (Pure ALOHA, Slotted ALOHA, ARRA) (time division and random transmission)

- Slotted “ALOHA” is considered appropriate for this type of applications



Satellite link : Frequency Allocation

- **Satellite VANET (possible) frequencies**
  - Frequency allocations to a given service depends on the region to be covered

- **Terrestrial VANET frequencies**

	Frequency [GHz]	Bandwidth [MHz]	Usual terminology
IEEE 802.11b	2.4	75	S band
IEEE 802.11p	5.9	75	C band

Type of service	Band	Remark
Military communications	EHF SHF UHF	Suffer high level of man-made radio noise (*e.g.* electrical equipment, automobile ignition systems)
MSS: handheld voice, and radio; Navigation	L	GNSS systems
FSS; Navigation; Broadcasting & FSS	C	Commercial satellite communication; Intelsat, American Domestic systems; GNSS systems; “shared” band
MSS: handheld voice, and radio	S	Shared band; used for GEO satellites (*e.g.* “Syncom”)
FSS	X	Reserved to administrations, government; GEO satellites
FSS, BSS	Ku	Current operational development (*e.g.* Eutelsat); absorption of the RF power by the atmosphere (w.c. rainfall attenuation)
Broadcasting, and FSS	Ku	Absorption of the RF power by the atmosphere (w.c. rainfall attenuation); partially shared.
MSS: handheld voice, and radio; Wideband: Internet, and multimedia	Ka	Large available bandwidth and reduced interference; used for GEO satellites absorption of the RF power by the atmosphere (w.c. rainfall attenuation)

Satellite link: LEO / MEO orbit trade-off (1 / 5)

- Dedicated LEO/MEO Link analysis has been addressed in Ka Band with the following guidelines:
  - Info Data rate = 500 bps (safety applications)
  - BER = 10^{-5} (safety applications)
  - Satellite and on-ground antenna envelope minimization
  - Atmosphere worst case conditions (*i.e.* rain)
  - Link Robustness to un-intentional interference (not expected in Ka)

Satellite link: LEO / MEO orbit trade-off (2 / 5)

It.	Uplink parameter	Gain / Loss	Signal value	Unit	Note
User side					f = 24 GHz
1	Tx power		10	dBW	
2	Tx antenna gain	15		dBi	Diam: about 3 cm
3	EIRP		25	dBW	
Propagation side					
4	Free space loss	208,01	-183,01	dB	Prop. Time : 83,8 ms
5	Polarization loss	0,5		dB	
6	Rain fall attenuation	11	-194,51	dB	
MEO satellite side					
7	Rx antenna gain	23,2		dBi	Diam. about 8 cm.
8	System noise temp.	24,81		dBK	G/T = -2,21 dBpK
9	C over N_0 (thermal)		**31,88**	dB-Hz	Eb/N_0 = 8,98 dB
10	Target Eb/N_0		8,8	dB	QPSK modulation
11	Eb/N_0 margin		0,18	dB	
12	IF protection level		**-191,14**	dB(W/m^2 Hz)	

Satellite link: LEO / MEO orbit trade-off (3 / 5)

It.	Uplink parameter	Gain / Loss	Signal value	Unit	Note
User side					f = 24 GHz
1	Tx power		10	dBW	
2	Tx antenna gain	15		dBi	Diam: about 3 cm
3	EIRP		25	dBW	
Propagation side					
4	Free space loss	194,29	-169,29	dB	Prop. Time : 17,2 ms
5	Polarization loss	0,5		dB	
6	Rain fall attenuation	11	-180,79	dB	
LEO satellite side					
7	Rx antenna gain	23,2		dBi	Diam. about 8 cm.
8	System noise temp.	24,81		dBK	G/T = -2,21 dBpK
9	C over N_0 (thermal)		**45,6**	dB-Hz	Eb/N_0 = 8,98 dB
10	Target Eb/N_0		8,8	dB	QPSK modulation
11	Eb/N_0 margin		13,90	dB	
12	IF protection level		**-163,74**	dB(W/m^2 Hz)	

Satellite link: LEO / MEO orbit trade-off (4 / 5)

It.	Downlink parameter	Gain / Loss	Signal value	Unit	Note
MEO satellite side					f = 20 GHz
1	Tx power		14	dBW	
2	Tx antenna gain	25		dBi	Diam: about 11 cm
3	EIRP		39	dBW	
Propagation side					
4	Free space loss	205,66	-166,76	dB	Prop. Time : 83,8 ms
5	Polarization loss	0,5		dB	
6	Rain fall attenuation	11	-178,26	dB	
User side					
7	Rx antenna gain	10	-168,26	dBi	Diam. about 1,5 cm.
8	System noise temp.	26,17		dBK	G/T = -16,77 dBpK
9	C over N_0 (thermal)		**33,58**	dB-Hz	Eb/N_0 = 10,68 dB
10	Target Eb/N_0		8,8	dB	QPSK modulation
11	Eb/N_0 margin		1,88	dB	
12	IF protection level		**-204,1**	dB(W/m^2 Hz)	

Satellite link: LEO/MEO orbit trade-off (4/5)

It.	Downlink parameter	Gain / Loss	Signal value	Unit	Note
LEO satellite side					f = 20 GHz
1	Tx power		14	dBW	
2	Tx antenna gain	25		dBi	Diam: about 11 cm
3	EIRP		39	dBW	
Propagation side					
4	Free space loss	178,42	-139,52	dB	Prop. Time : 17,2 ms
5	Polarization loss	0,5		dB	
6	Rain fall attenuation	11	-161,02	dB	
User side					
7	Rx antenna gain	10	-141,02	dBi	Diam. about 1,5 cm.
8	System noise temp.	26,17		dBK	G/T = -16,67 dBpK
9	C over N_0 (thermal)		**60,91**	dB-Hz	Eb/N_0 = 38,01 dB
10	Target Eb/N_0		8,8	dB	QPSK modulation
11	Eb/N_0 margin		29,21	dB	
12	IF protection level		**-176,2**	dB(W/m^2 Hz)	

Satellite link: LEO / MEO orbit trade-off (5 / 5)

Parameter	LEO	MEO
Uplink C/N_0 [dB-Hz]	45.6	31.88
Downlink C/N_0 [dB-Hz]	60.91	33.58
End–to–End C/N_0 [dB-Hz]	45.47	29.56
Max Uplink C/I_0 [dB-Hz]	32	45
Max Downlink C/I_0 [dB-Hz]	46	48
E_b/N_0 Margin [dB]	**13,77**	**0,04**

Considerations:

1. LEO link shows **better margin** (as expected)
2. Consequently LEO link appears more robust to **interference**
3. On the other side, LEO orbit requires **more satellites**
4. **Antenna** envelope is:
   - Satellite: 8 and 11 cm
   - On-ground: 3 and 1.5 cm

   low impact to satellite earth deck
   (indicated for “piggy-back” payload missions)

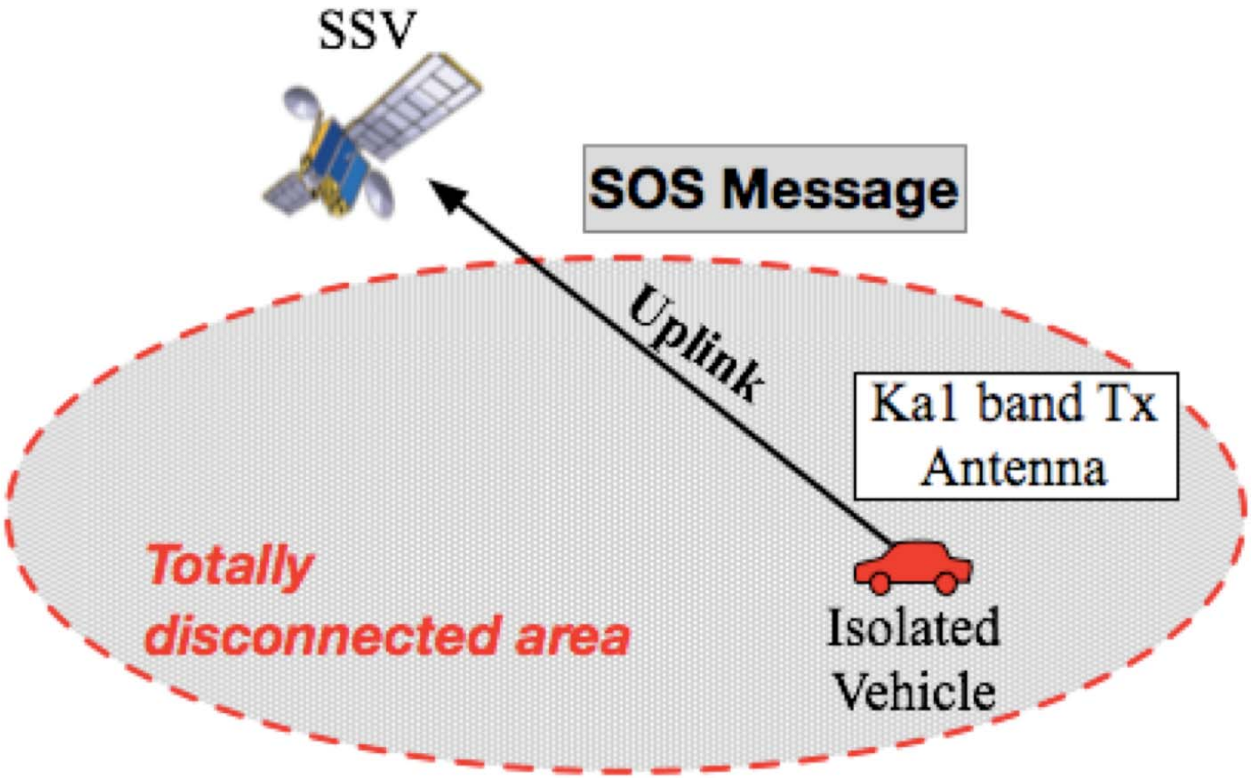
5. MEO orbit permits **possible GNSS evolution**

Connectivity Guidelines

- **Minimum requirements**:
  - Vehicle equipped by GNSS Receiver, and by Ka Transceiver
- **GNSS Rx** provides information about:
  - Number of Satellites (SSV) in visibility;
  - Isolated Vehicle position;
- **Ka Tx/Rx** permits the link with the MEO SSV

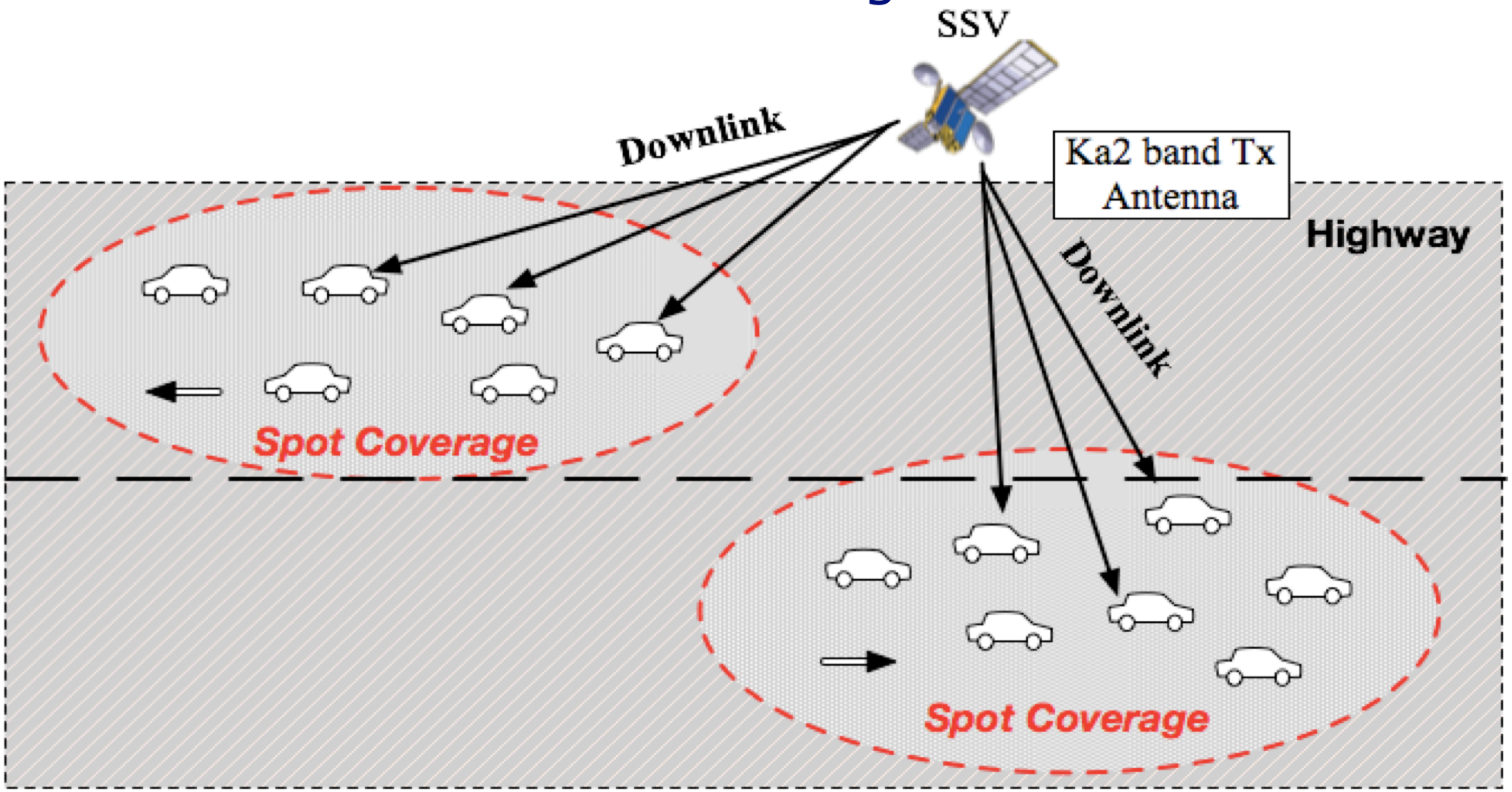
User case: Isolated Vehicle (1/4)

1. An isolated vehicle transmits a message to transparent SSV in visibility by **Ka1 band Tx** antenna (Forward Link –*uplink*)



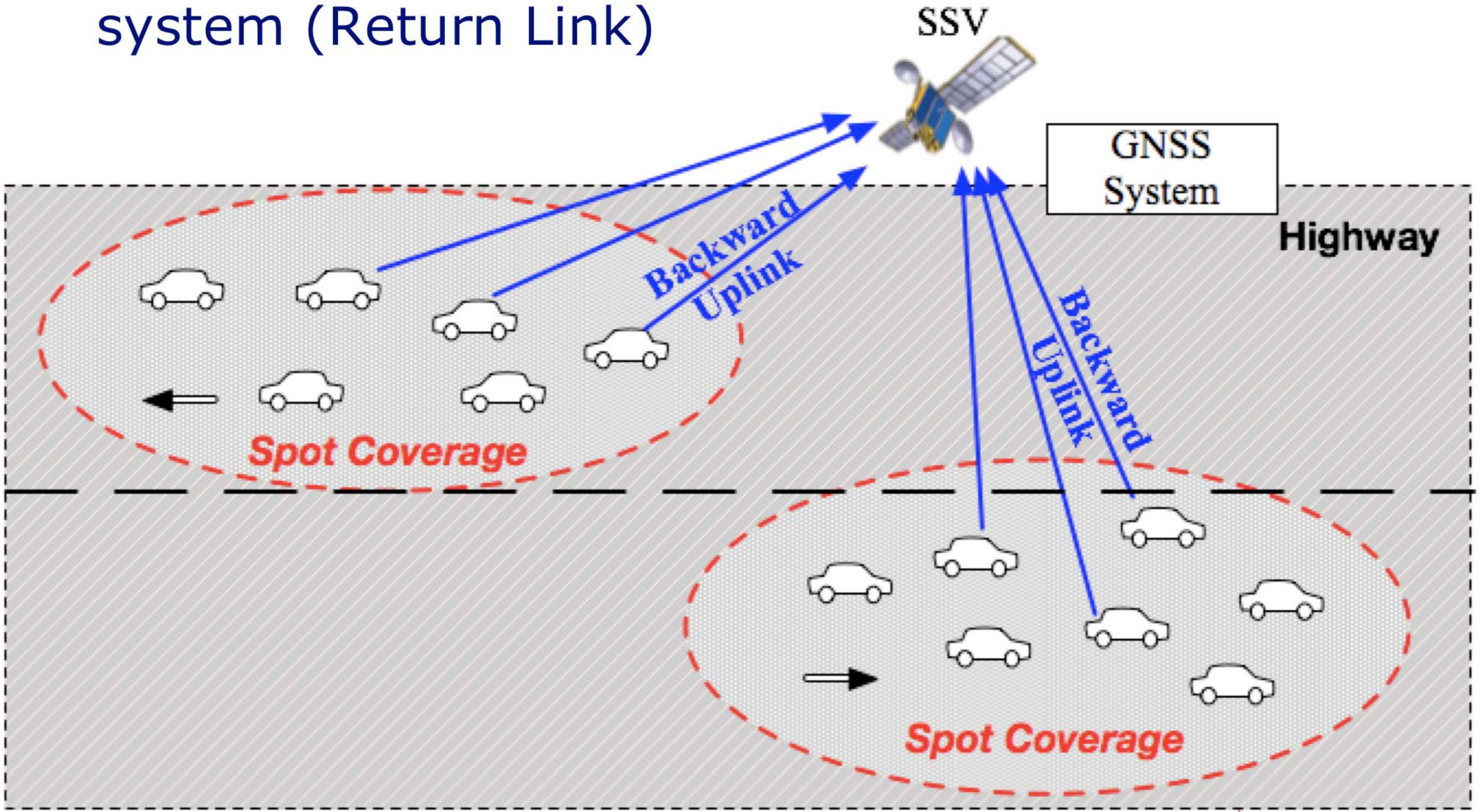
User case: Isolated Vehicle (2/4)

2. SSV forwards at **Ka2 band** to ground by spot coverage (Forward Link -*downlink*)
3. Cluster of cars / Ground Service provider receives the forwarded distress message



User case: Isolated Vehicle (3/4)

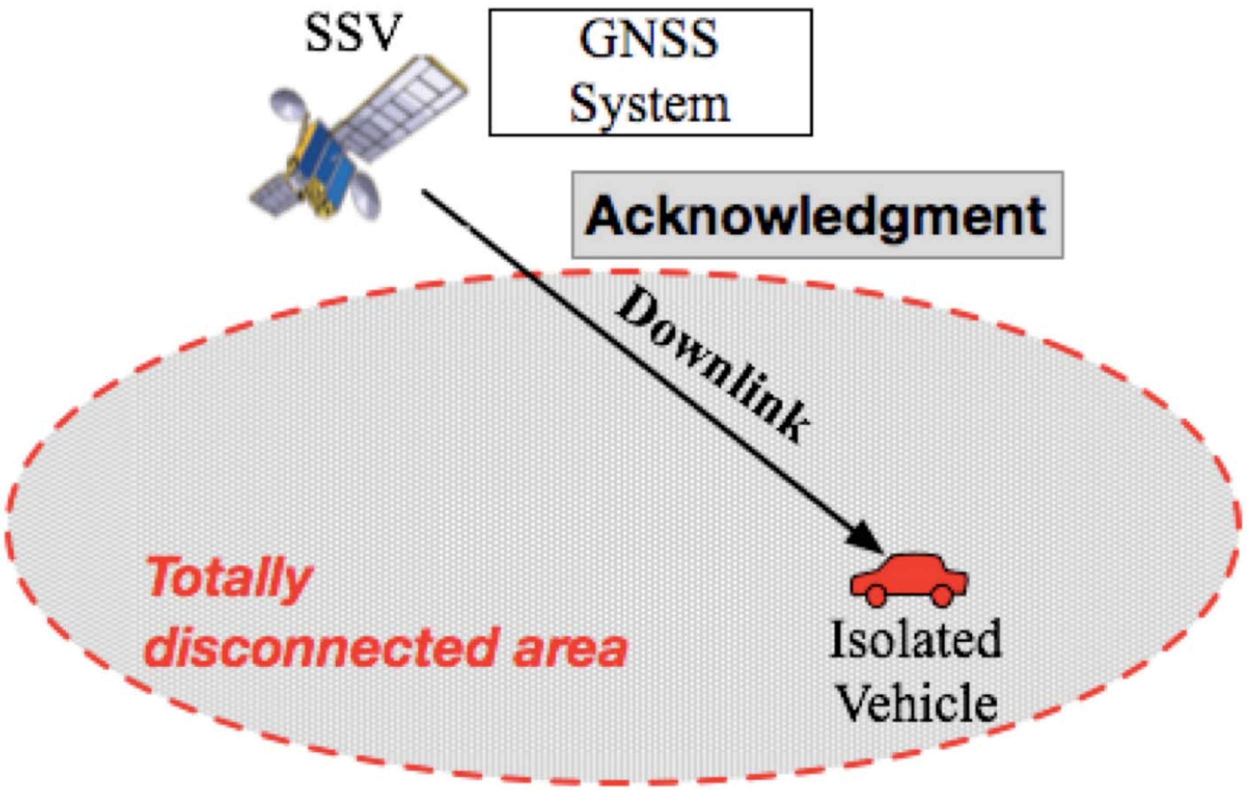
4. Acknowledgement message transmitted by GNSS system (Return Link)



ISO IEC ITU International Telecommunication Union

User case: Isolated Vehicle (4/4)

5. User receives the acknowledgement;
6. Transmission concluded.



Conclusions

- ***Medium-range*** communication extension with satellite support;

- **Emergency** and **safety** applications in VANETs, (isolated area with no V2V or V2I);

- **Feasibility study** has been addressed in terms of frequency allocation, access technique and orbit tradeoff.

Thank you for your attention

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