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Opportunistic Vehicular Networks by Satellite Links for Safety Applications

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Satellite radio is one of a complementary set of network connectivity technologies in future vehicles equipped with *on-board* computers. Others include Bluetooth, Wi-Fi, WiMax, UMTS, and DSRC. Collectively these technologies can enable vehicle-to-vehicle and vehicle-to-Internet connectivity, but under different operating conditions.

When a vehicle is driving alone in an area that is devoid of telephony infrastructure area (*i.e.*, a rural area during night hours), or it is in a disaster and emergency situation, a satellite network can provide service connection.

In this paper we investigate the relationship between satellite radio connectivity and other opportunistic connectivity schemes that rely on short-range communication. We also describe an opportunistic vehicular networking scheme for safety applications, based on satellite communication links (*i.e.*, LEO/MEO satellite constellations). In such scenario (see Figure 1 (*left*)), a vehicle (called as isolated vehicle) is driving alone on the road (*i.e.*, the traffic density reaches the minimum value), and no radio coverage (*e.g.*, no Wi-Fi access points, or cellular base stations).

In this example, the isolated vehicle seeks to send an SOS message to any neighboring vehicle to alert about an accident occurred. The SOS message (where the vehicle's position is stored) is sent to the satellite in view (*i.e.*, LEO/MEO satellite constellations) by the vehicle (*uplink* connection). When the satellite receives the SOS message, it will forward to the ground by spot coverage ("*forward link*"). Consequently, the SOS message will be received by clusters of vehicles.

In the *return link* an acknowledgment is sent to the satellite in visibility, which forwards it to the isolated vehicle. The proposed scheme shows how the satellite connectivity can solve the problem of seamless and ubiquitous connectivity, when a vehicle is driving alone in an isolated area. The satellite works as '*bridge*', in order to connect the vehicle to the closest cluster of vehicles, driving in an urban area.

A physic layer analysis has been addressed in order to evaluate (*i*) the minimum distance among cluster of vehicles and isolated user vs. satellite orbit (LEO/MEO tradeoff), (*ii*) the service availability along a selected time window (*e.g.*, from 0 a.m. to 6 a.m.), (*iii*) the LEO/MEO satellites visibility from uplink and downlink coverage ("end-to-end" visibility), (*iv*) link feasibility and availability (*i.e.*, "end-to-end" Signal-to-Noise and Interference ratio), (*v*) *forward link* delay, and payload dimensioning. An example of visibility analysis for MEO constellation (*i.e.* Galileo) is reported in Figure 1 (*right*), where we considered East Rome as point of reference. Our technique is intended to augment short and medium-range communication to bridge isolated vehicles or clusters of vehicles when no other mechanism is available.

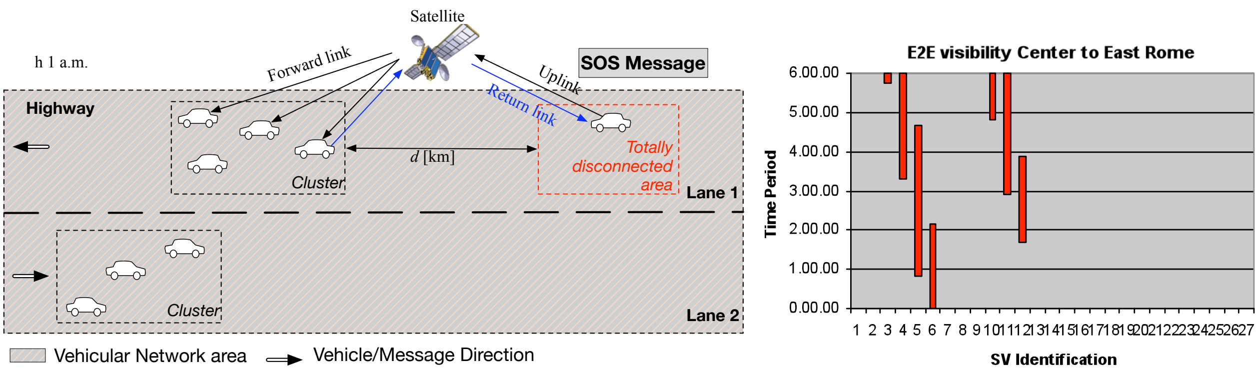

Figure 1. (*left*) Novel opportunistic networking scheme in a VANET scenario with satellite connectivity for safety applications. (*right*) Forward link end-to-end (E2E) visibility, Rome city vs. East Rome.