Communications in ITS

for cooperative systems deployement

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Intelligent Transportation Systems （ITS） background and societal motivations

- **Reduce road fatalities is the primary public objective**

  1- Provide road operators the possibility to warn drivers for route hazard or using communication systems for impact avoidance.

  2- Develop **Road safety service** (eg. emergency call, halt vehicle, vehicle in wrong way, hard braking, speed limits violation, curve speed warning)

- **More efficient and greener mobility**

  1- Transportation and traffic regulation optimized, allowing reduction of petrol consumption and emissions of green house effect gases

  2- Traffic management service (ex road information, traffic information and relief routes, weather information, congestion aware navigation systems)

  3- Telematic services for better Electrical Vehicles (EV) management

- **New market opportunity**

  1- Connection to the internet everywhere in a road depending on radio coverage and technology used, providing infotainment services for increasing passengers comfort

  2 - Opportunity to develop M2M services between car sensors and a remote server

  Mobility and comfort services for drivers and passengers (ex POI for EV, multimodal Platform, traveler information, M2M services, electronic payment with NFC…)

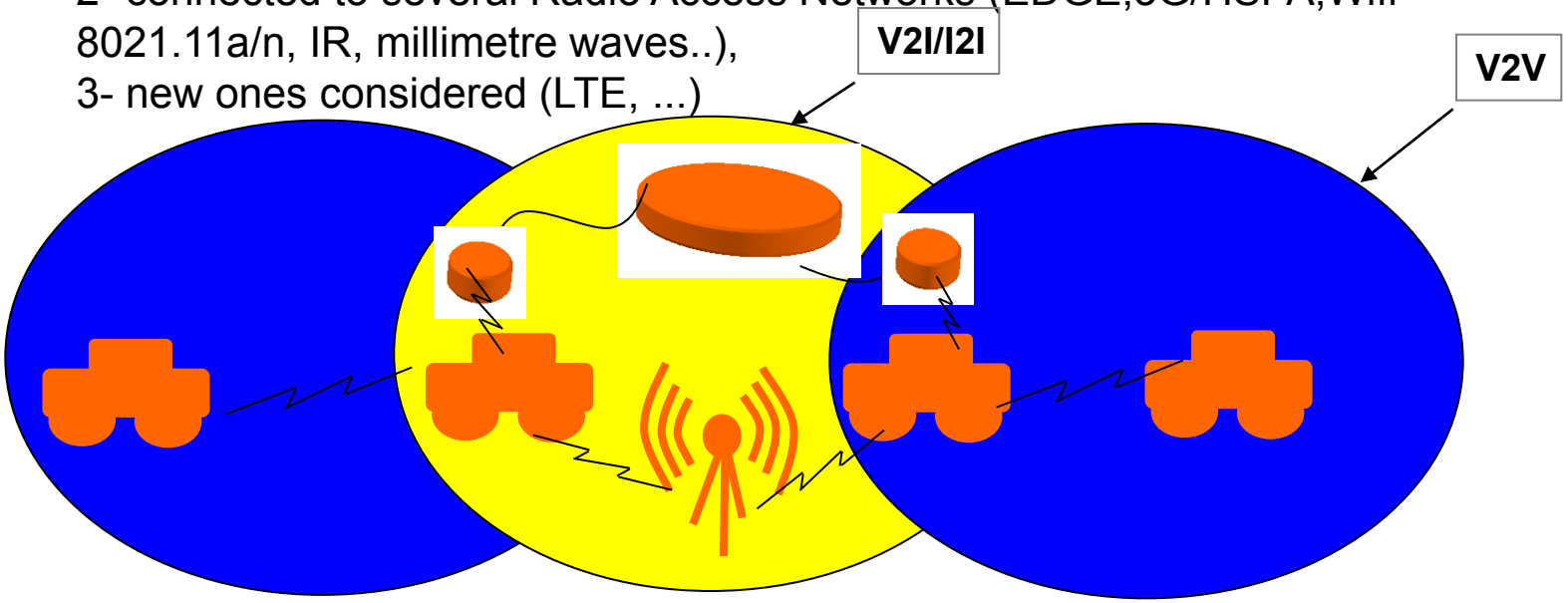
Connectivity and cooperation

at the heart of ITS

ITS communications are possible in two modes with combination of them :

- **Vehicle to Vehicle communication (V2V)**
  1- specifically with IEEE802.11 radio technology
  2- new amendment 802.11 p designed for MAC and PHY layers
  3- objective to achieve low latency communications in short coverage areas (DSRC)

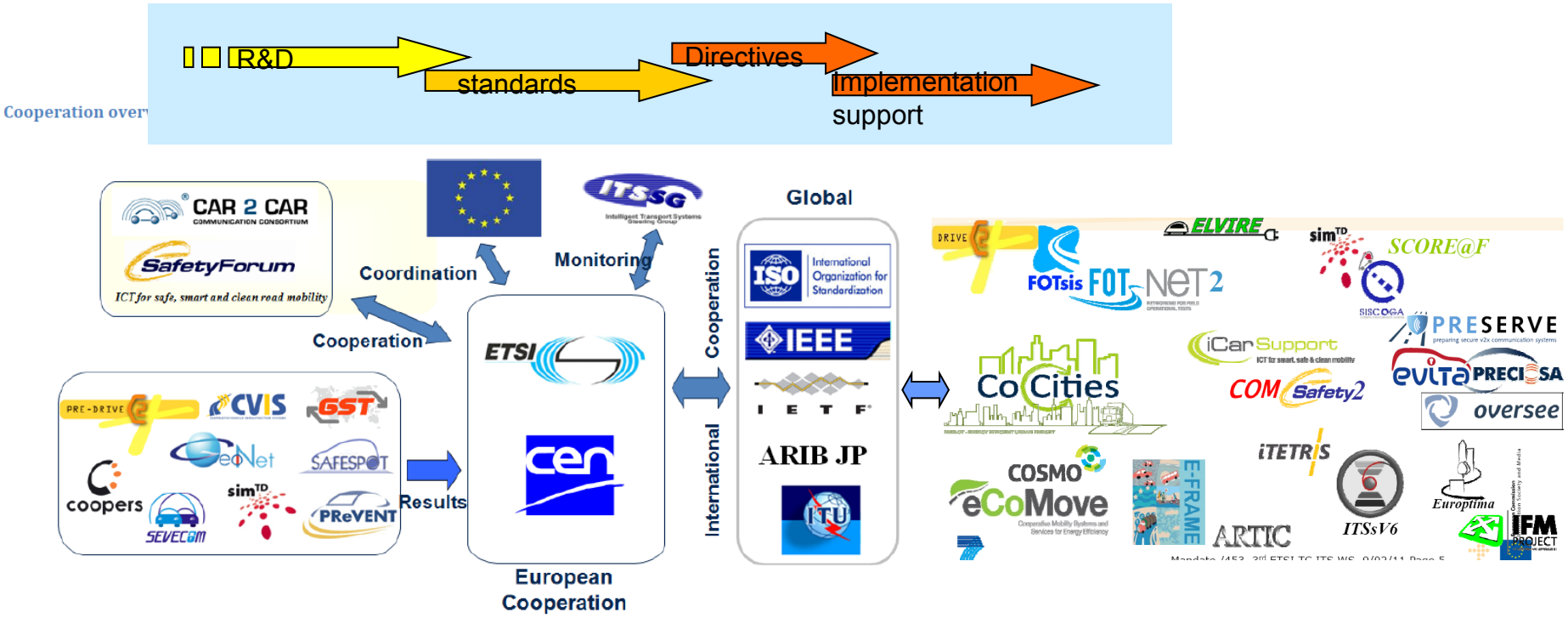
- **Vehicle to Infrastructure (V2I / I2V / I2I)**
  1- new access technology IEEE 802.11p designed for DSRC
  2- connected to several Radio Access Networks (EDGE,3G/HSPA,Wifi 8021.11a/n, IR, millimetre waves..),
  3- new ones considered (LTE, ...)



Communications Standardization initiatives

at the heart of ITS systems deployement

- Requirement of CE to get **harmonization** and coordination in worldwide ITS initiatives and developments (Asian, Europe, USA)
- EC mandate 453 to issue a coherent set of standards, specifications and guidelines to support EU wide implementation and deployment of Cooperative ITS systems, ETSI and CEN are involved in EC/M453
- EC directive on ITS (july 2010): 4 priority domains and 6 priority actions : adoption of specifications for priority action(s) by 27/02/2013, 12 months after adoption, EC presents to European Parliament and European Concil a proposal for the deployment of this action

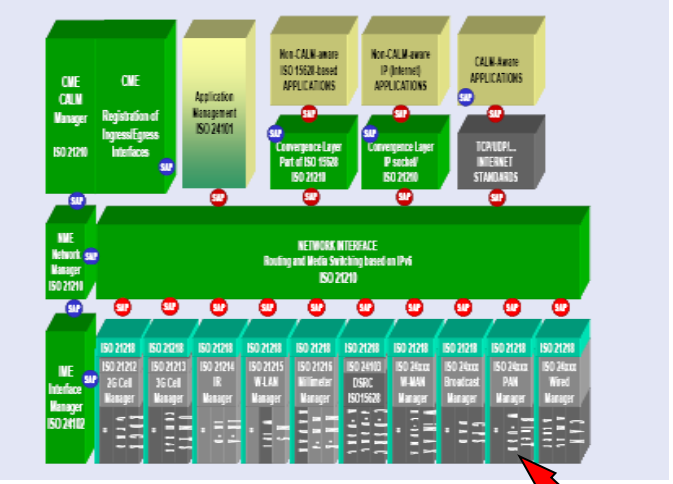


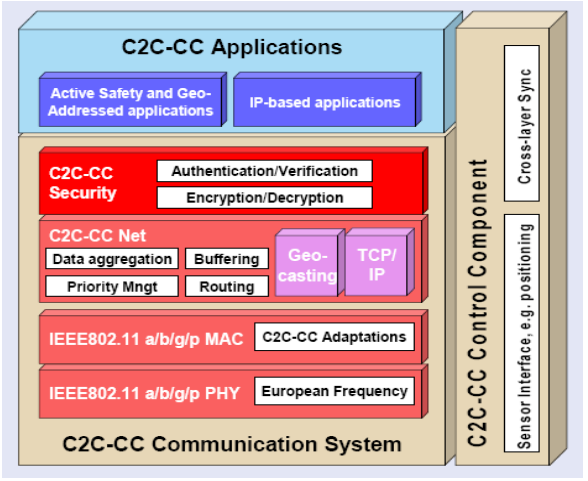
Comparison of technology for cooperative systems

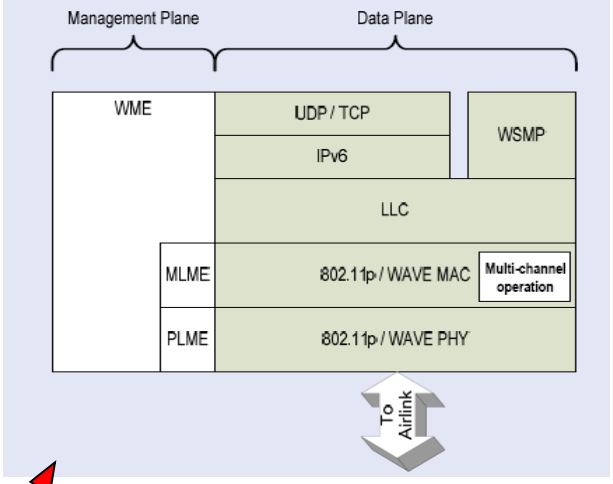
Technology	IEEE 802.11n	IEEE 802.11p	3G/HSPA	LTE
Capacity	50-100Mbps (MIMO)	3 to 5 Mbps	14Mbps	100Mbps in 20MHz channel (MIMO)
Speed	High speed capacity	High speed capacity (doppler spread sensitive)	High speed capacity	High speed capacity
Coverage distance	A few km in open field	500m	A few km in open field	A few km in open field
Type of communications	V2I	V2V	V2I	V2I
QoS	EDCA parameters (802.11 e)	EDCA parameters (802.11 e)	RAB and radio resource allocation	SAE Bearer: GBR, MBR…delay, PER
security	WPA2	PKI with cryptography	USIM card, authentication, cryptography	USIM card Authentication AKA encryption
E2E delay	<250ms	<100ms	<a few hundred of ms depending on the cell load	100ms

V2V Standardization initiatives

at the heart of ITS systems deployement







CALM continuous communications for vehicles

CAR 2 CAR COMMUNICATION CONSORTIUM

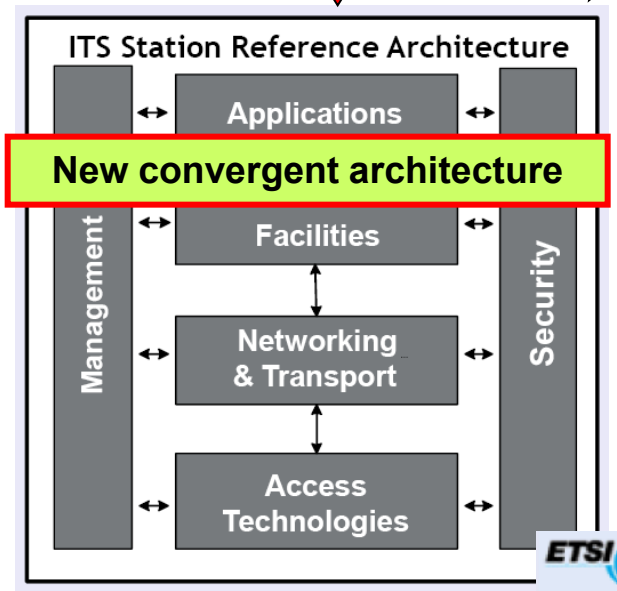
IEEE

3 Standardisation bodies :

ISO TC 204 WG 16 : Started in 2001, WG16 of the International Technical committee 204 developed architecture ***CALM (Communications Access for Land Mobiles)***

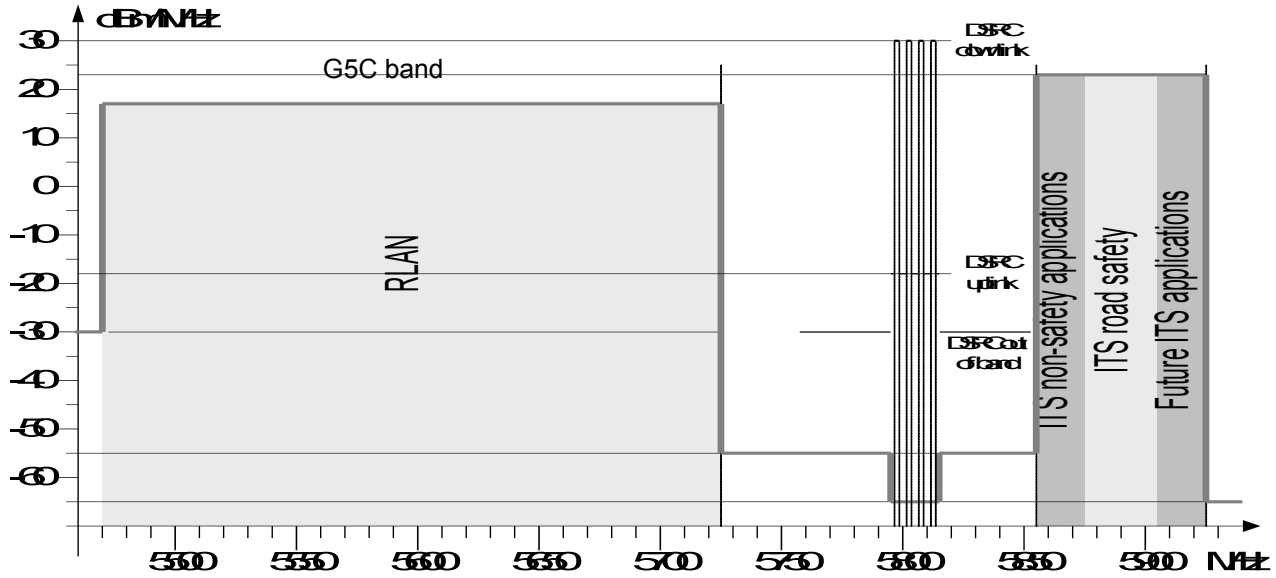
ETSI ITS TC : founded in 2007, ETSI involved in EC Mandate M453 to develop a minimum common set of standards for European needs and deployment.

IEEE WAVE 1609 : American WG created since 2006 developing ***WAVE (Wireless Access in Vehicular Environment)*** architecture based exclusively on top of IEEE 802.11p and ASTM1609



ETSI

ITS G5 profile : The Physical layer for EU V2V



Frequency range	channel	service
5875MHz to 5905MHz - **G5A**	**G5CC in G5A** / 10MHz	Road safety and traffic efficiency (control channel)
5855MHz to 5875MHz - **G5B**	**G5SC1 and G5SC2 in G5A** / 10MHz	road safety and traffic efficiency (service channel) SA service announcements of services operated on G5SC1 to G5SC5
5470MHz to 5725MHz - **G5C**	**G5SC3, G5SC4 in G5B** and G5SC5 in WLAN	Non safety applications and other ITS applications
5905 MHz to 5925MHz	5905 MHz to 5925MHz	Future ITS applications

ETSI ITS-G5 : MAC and PHY layer enhancements

- **PHY :**
  - OFDM mod of 802.11a
  - 10MHz channels, double GI, MCS 2 for G5CC and G5SC1, MCS 4 for other G5SCs

MCS	0	1	2	3	4	5	6	7
Data rate in Mbit/s 40 MHz channels	12	18	24	36	48	72	96	108
Data rate in Mbit/s 30 MHz channels	9	13,5	18	27	36	54	72	81
Data rate in Mbit/s 20 MHz channels	6	9	12	18	24	36	48	54
Data rate in Mbit/s 10 MHz channels	3	4,5	6	9	12	18	24	27
IEEE RATE coding R1 ... R4	'1101'	'1111'	'0101'	'0111'	'1001'	'1011'	'0001'	'0011'
Modulation scheme	BPSK	BPSK	QPSK	QPSK	16-QAM	16-QAM	64-QAM	64-QAM
Coding rate R	1/2	3/4	1/2	3/4	1/2	3/4	2/3	¾

- **MAC : CSMA/CA MAC + 802.11e QOS**
  - No more association, authentication, probe request (scan) in Management frames.
  - New Timing Advertisement Management frame: (Synchronization using TSF)
  - new EDCA 802.11 parameters (QoS) mapped to logical channels: CCH with optimized CW and AIFSN

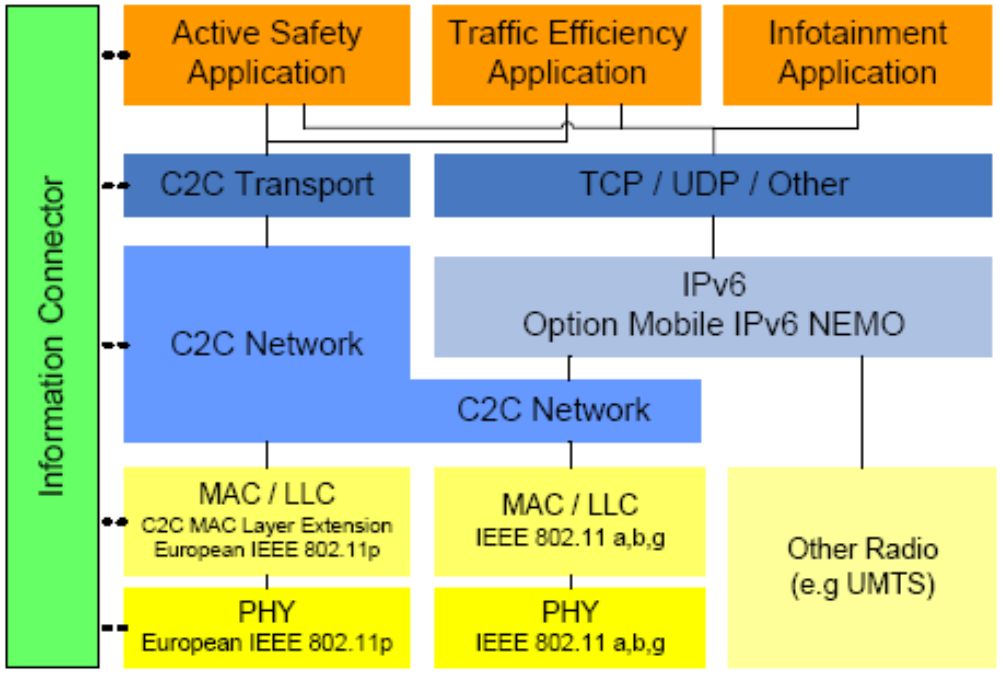
- **Control channel**
  - Broadcast communication
  - Dedicated to short, high-priority, data and management frames:
  - Safety-critical communication with low latencies
  - Initialization of two-way communication on SCH

- **Service channel**
  - Two-way communication between RSU and OBU or between OBUs
  - For specific applications, e.g. tolling, internet access
  - Different kinds of applications can be executed in parallel on different service channels

Channel type	Centre frequency	IEEE [3] channel number	Channel spacing	Default data rate	TX power limit	TX power density limit
G5CC	5 900 MHz	180	10 MHz	6 Mbit/s	33 dBm EIRP	23 dBm/MHz
G5SC2	5 890 MHz	178	10 MHz	12 Mbit/s	23 dBm EIRP	13 dBm/MHz
G5SC1	5 880 MHz	176	10 MHz	6 Mbit/s	33 dBm EIRP	23 dBm/MHz
G5SC3	5 870 MHz	174	10 MHz	6 Mbit/s	23 dBm EIRP	13 dBm/MHz
G5SC4	5 860 MHz	172	10 MHz	6 Mbit/s	0 dBm EIRP	-10 dBm/MHz
G5SC5	As required in [2] for the band 5 470 MHz to 5 725 MHz		several	dependent on channel spacing	30 dBm EIRP (DFS master)	17 dBm/MHz
					23 dBm EIRP (DFS slave)	10 dBm/MHz
NOTE: With respect to emission limits (power limit / power density limit), the more stringent requirement applies.						

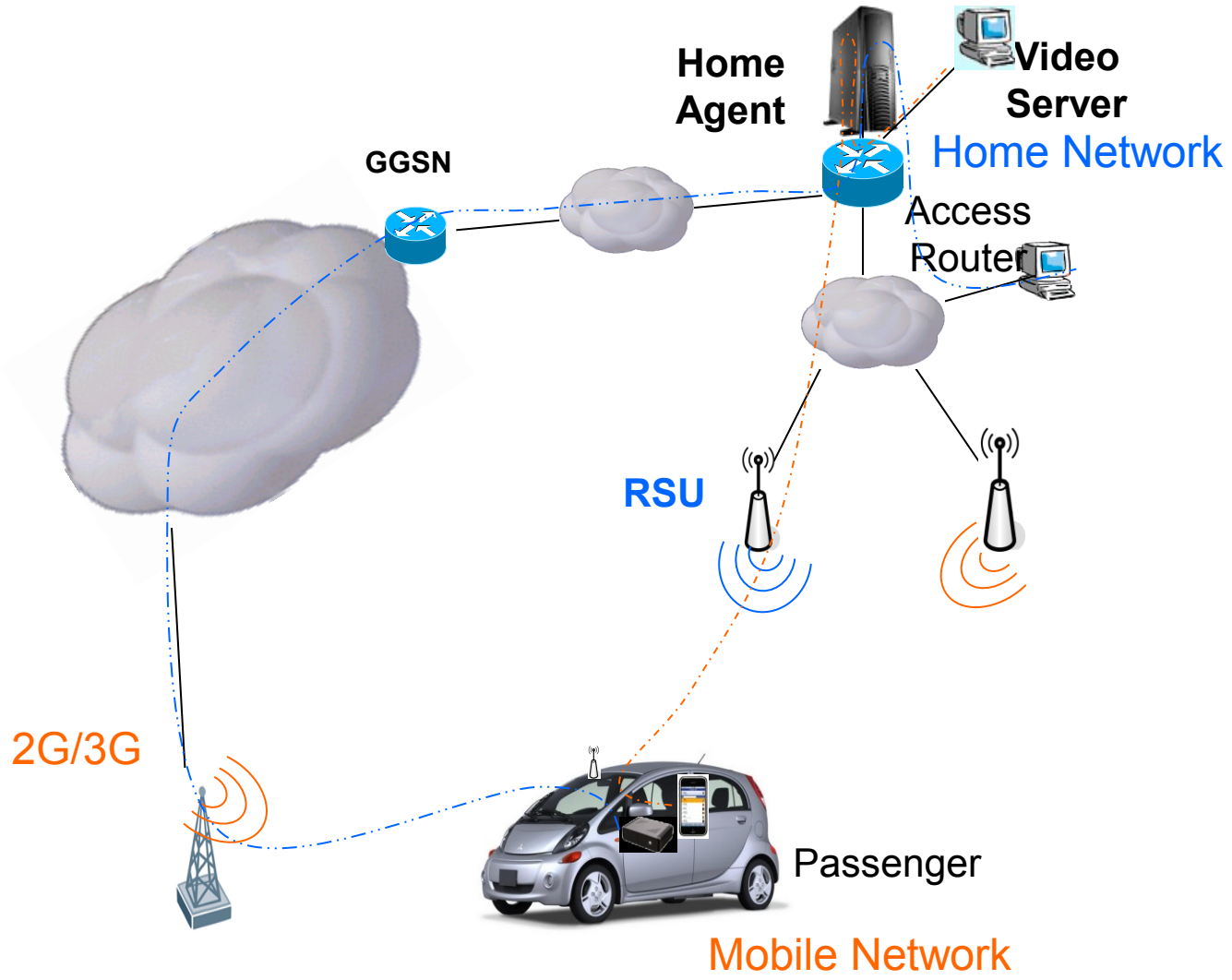
C2C-CC architecture : outcomes integrated in ETSI ITS

- **C2C Network Layer**
  - wireless multi hop communications based on geographical addressing and routing protocol
  - Location table, beaconing, location service, geographical addressing, forwarding algorithms
- **congestion control**
  - priority handling, load indication from wireless channel, transmit power control, packet discard mechanisms, data and packet rate control
- **CAM messages in facilities layer**
  - (Cooperative Awareness Messages (CAMs) distributed within the ITS-G5 (802.11p) network
  - information of presence, positions, status of communicating ITS stations to neighboring ITS stations located within a single hop distance.

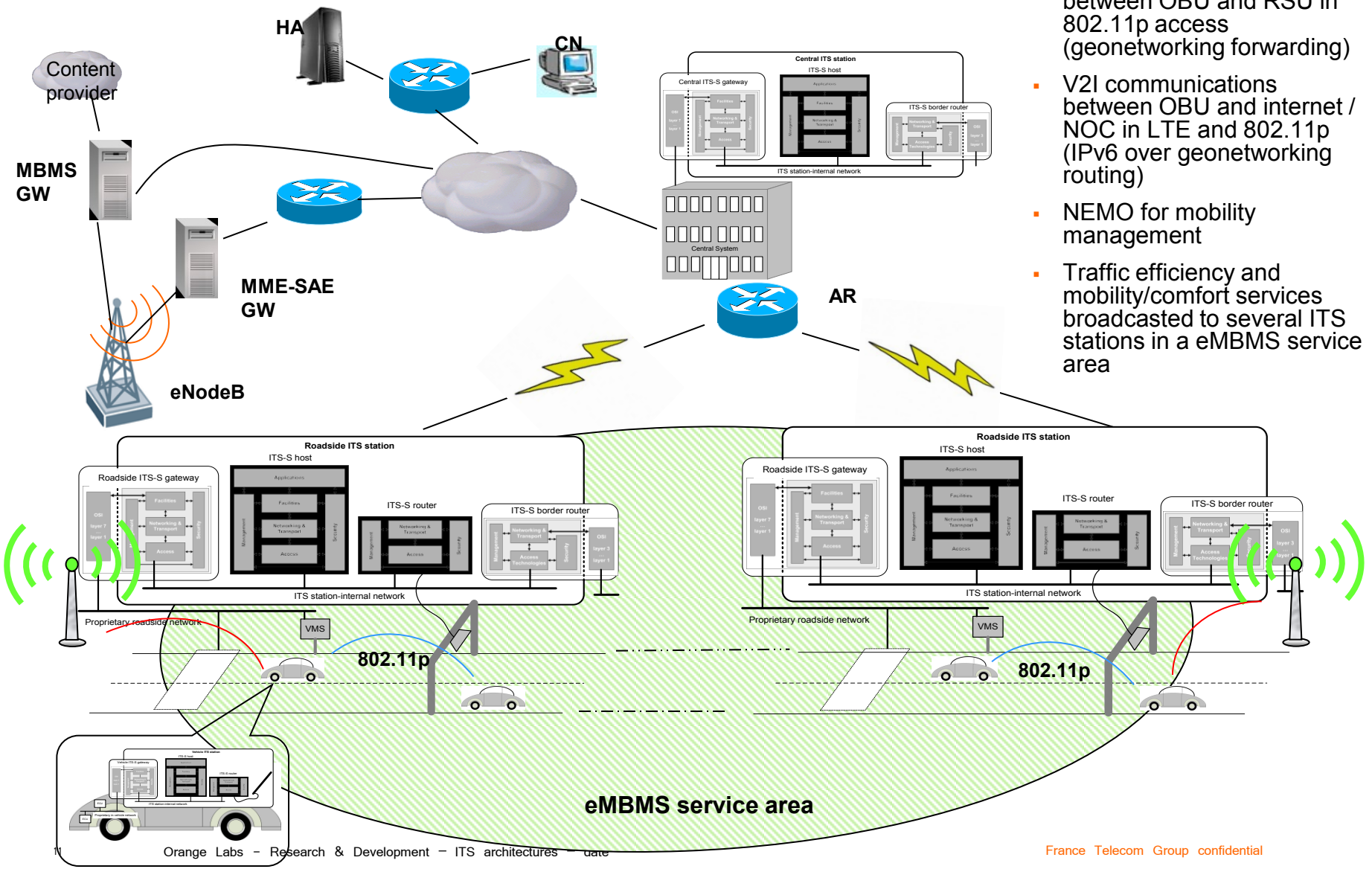


Network complementarity and mobility management

- IPv6 stack implemented in mobile router
- Mobile IPv6 (tunneling)
- NEMO (network mobility management)
- Multi Care of address (simultaneous access networks) multihoming
- QoS for traffic prioritization



LTE and cooperative systems



- V2V communications between OBU and RSU in 802.11p access (geonetworking forwarding)
- V2I communications between OBU and internet / NOC in LTE and 802.11p (IPv6 over geonetworking routing)
- NEMO for mobility management
- Traffic efficiency and mobility/comfort services broadcasted to several ITS stations in a eMBMS service area

Stakes on actual standards

- **Congestion control** of access networks, contention in the CCH in 802.11p technology can be easily achieved, DCC (Decentralized Congestion Control) mechanism proposed by ETSI is a complex architecture
- **QoS policy at level 3** (IP level) applied to control the bandwidth occupation and enable congestion avoidance
  - QoS policy implementation enables bandwidth estimation with flow priority according to traffic classes by applying queuing disciplines to guarantee urgent flow transmission
- **Security issues** protection against malicious manipulations and masquerade of message information (ex road safety messages)
  - Flat PKI (Public Key Infrastructure) infrastructure (public +private keys distributed by a CA (Certificate Authority), Share of security with emission of the certificate by the CA and registration of the vehicle by the RA (Registration Authority). Long term certificates and pseudonym certificates to guarantee anonymity for authentication, integrity and confidentiality
- **Privacy** respect of private information owned and transmitted by the vehicle (ex vehicle tracking), NLOS (Non Line Of Sight) communications in V2I and V2V involve frequent advertising of position in safety beacons (CCH) → broadcast of certificates (beacons/warnings and periodic messages)
  - Privacy in case of CA: Centralized organization, Multiplication of CA or same CA sent multiple times, change of signed key, need of computation capacity
  - Privacy in case of non CA: To keep high level of privacy, efficient revocation to react to untrustworthy way detection (Revocation Certificate List - RCL), Impact of large number of users : key collision, collapse, poor revocation capacity

Conclusions

Challenges

- A lot of stakes concerning security, QoS and cross layer management remain
- 3GPP proposal for other network cooperation, use of ANDSF (Access Network Discovery Service Function) server to spread information on the access network topology and mobility rules
- The CI/ITS application mapping engine inside the ITS station can benefit from these advanced features to efficiently manage the ITS communication profiles
- Will it still make sense in 2017?

Benefits

- Increased capacity and coverage
- Enabler to provide full fledge of connected services from safety and warning towards connected navigation & infotainment
- Cost efficient enabling sustainable business models

Operators contributions

- Telecommunication operators have a complete role to play, to manage complementarity of operator networks with ITS networks in an efficient way to support V2V and V2I communications in cooperative networks