Status of the C2C-CC Phy/Mac/Net Working Group

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Outline

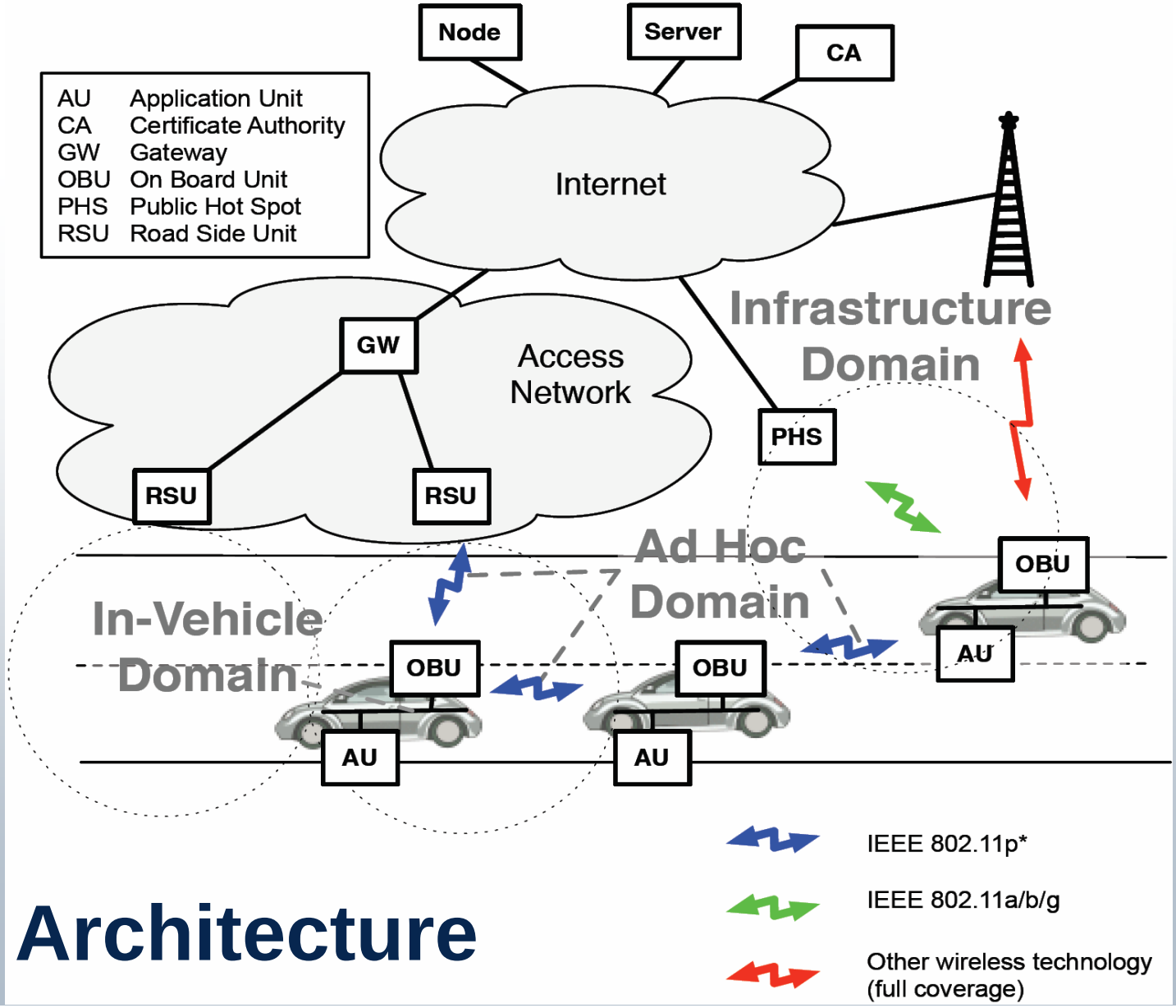
- Introduction
- System Architecture and Working Groups

- Physical Layer and Spectrum allocation
- MAC Layer – 802.11p*/WAVE
- NET Layer

Introduction

- This presentation is mainly based on:
  - the C2C-CC Handbook
    - A “living document” which summarizes and describes the main building blocks the Car2X Communication System
  - the C2C-CC Lead Document
    - A “living document family” which summarizes the current state of the Physical Layer, the Data Link Layer, and the Network Layer standardization for vehicle-to-vehicle and vehicle-to-infrastructure communication
  - and on the ongoing WG issues

Reference Architecture



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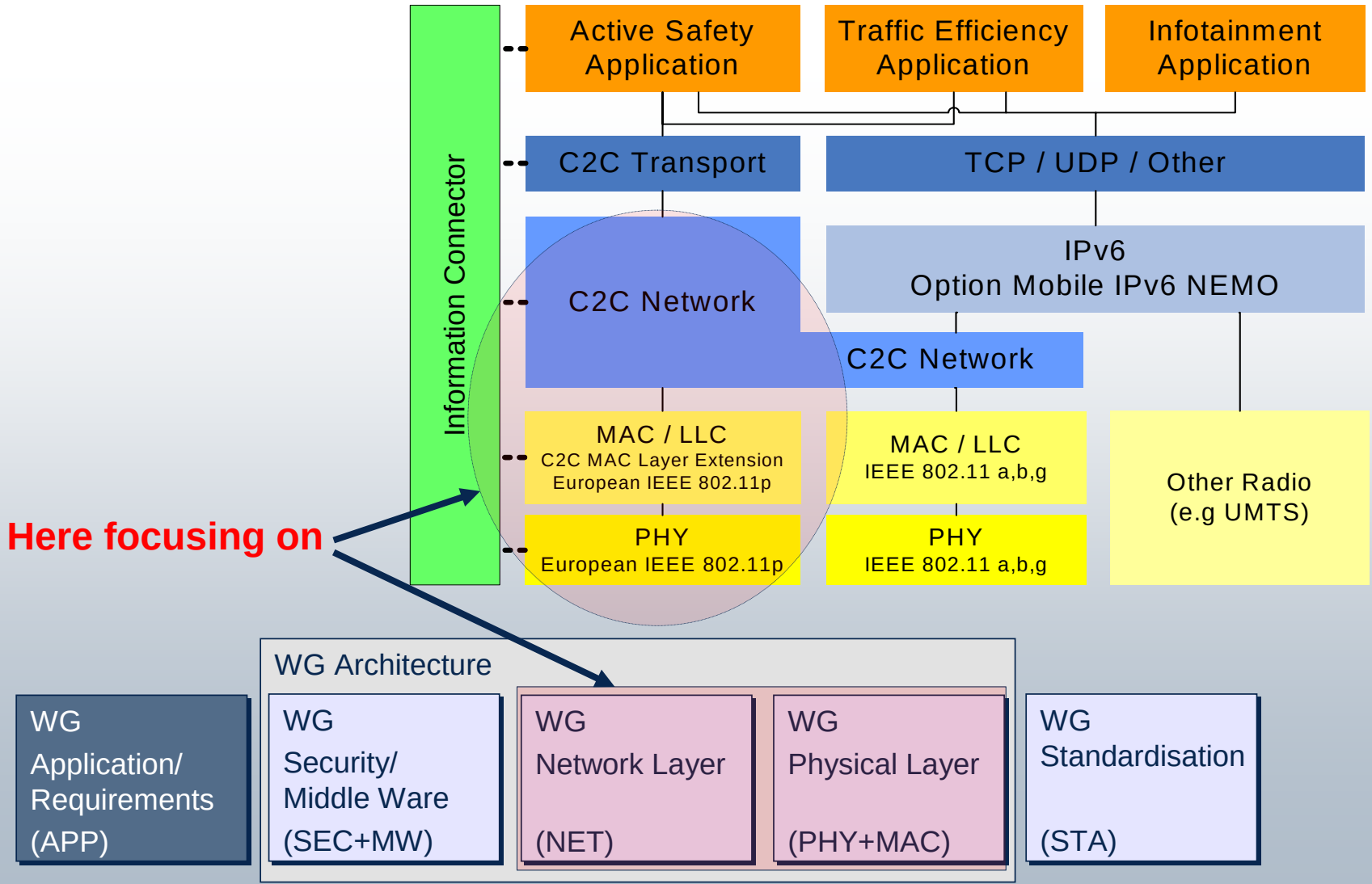
Unit Architecture and C2C-CC WGs



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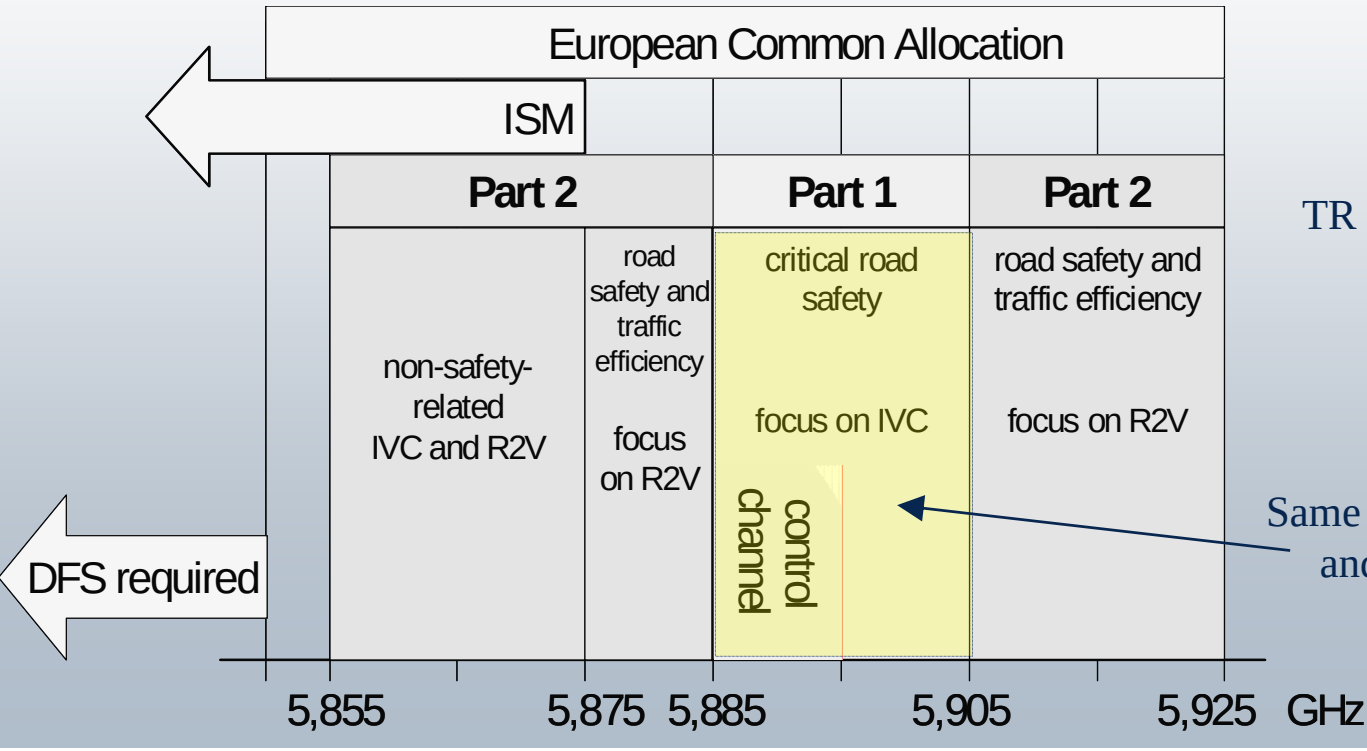
Main “obstacles” to a C2X Standard

- Absence of a royalty free European-wide exclusive frequency band allocation for active safety Car2Car applications
- Lack of stability of IEEE802.11p standard draft,
  - the upcoming C2C-CC industrial standard for the lower OSI layers will be based upon a **European version of IEEE802.11p**
  - But in general IEEE 802.11p (Wireless Access for Vehicular Environment WAVE) and IEEE 802.11a will be the technical basis for the physical layer of the C2C-CC radio system.

Radio Frequencies

- Robust Active Safety vehicular communications need an effectively **protected frequency band** (not ISM bands).
- For this reasons the C2C-CC supports the allocation of such frequency band and agrees to **ETSI proposal**:



ETSI technical reports:
TR 102 492-1 and TR 102 492-2

Same Control Channel (178) of US, and channel 180 as 2nd Safety Channel

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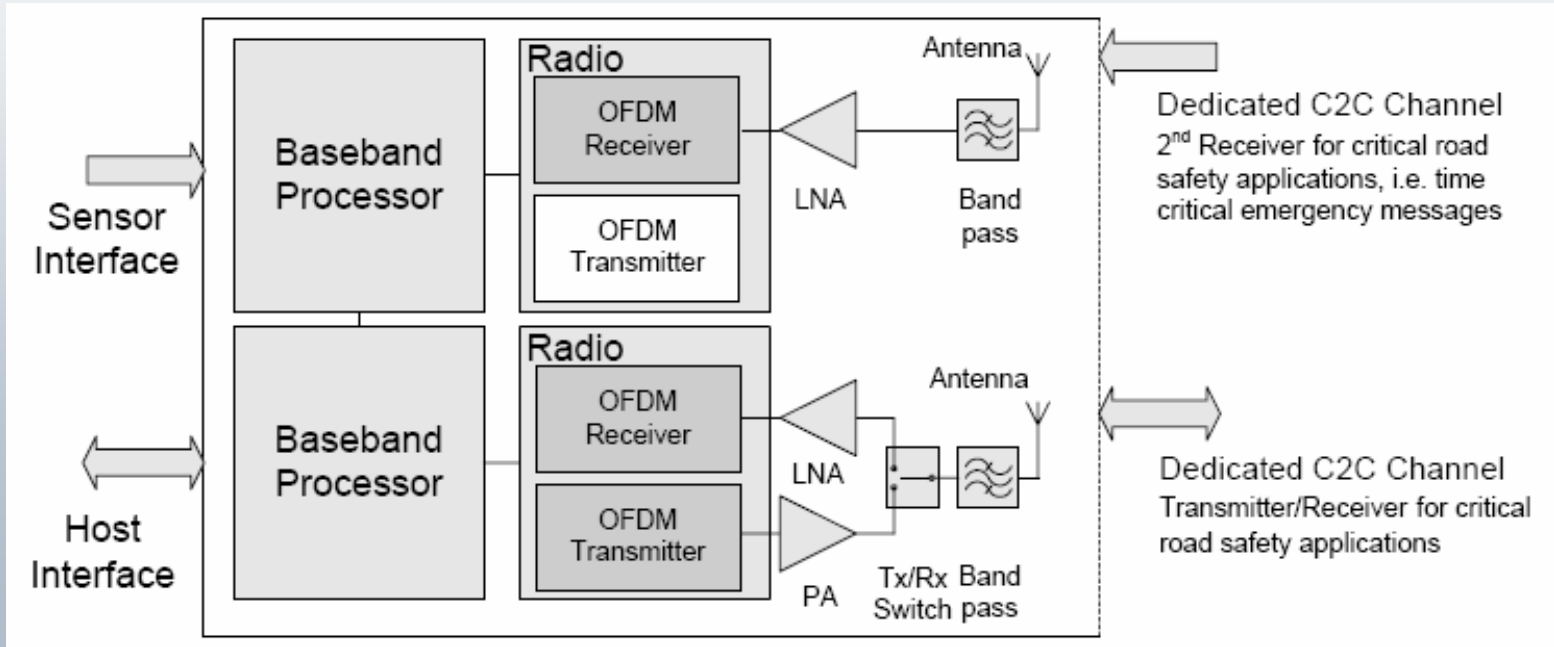
C2C-CC Radio System

- For active safety applications a bandwidth of **2 x 10 MHz contiguous channels** is required, one channel for network control and safety purpose and the second for safety applications only.
- The communication system shall be able to **receive simultaneously on the two neighbored channels**. The received signals may originate from different transmitters.



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C2X PHY Layer characteristics

- the C2X-RS PHY specification is based on the upcoming IEEE802.11p standard (WAVE), and will be adapted for European usage

Parameter	Value	Comment
Maximum radiated power	33 dBm e.i.r.p.	Transmitter power control (TPC) with a 30 dB range. Equipment classes: A 10 dBm; B 20 dBm; C 33 dBm
Frequency stability	1ppm	This figure takes account of the frequency tolerance allowed by IEEE 802.11a, together with the expected Doppler variation from a vehicle closing speed of 400 km/h.
Modulation scheme	BPSK, QPSK, 16QAM, 64QAM	This is the standard set within IEEE 802.11a and p.
Data rates	3/4.5 /6/9/ 12/18 /24/27 Mbit/s	This is the standard set within IEEE 802.11a, j and p. As an option two channels may be combined to produce double data rates (up to 54 Mbit/s). Default data rate is 6Mbit/s.
Communication mode	Half-duplex, broadcast	Half-duplex and broadcast are believed to be adequate for the applications considered to date.

- the WAVE draft IEEE P802.11p also is based on P802.11REVma™
- The PHY layer consists of two sub layers, the
  - **PMD** Physical Medium Dependent system whose function defines the characteristics and method of transmitting and receiving data through a wireless medium between two or more stations, each using the **OFDM** system.
  - **PLCP** PHY convergence function, which adapts the capabilities of the PMD system to the PHY service.

Communication types and categories

Communication type	Speed up to	PSDU length	Maximal allowed PER
R2V	140 km/h	1000 Byte	< 10%
R2V	250 km/h	200 Byte	< 10%
V2V	500 km/h	200 Byte	< 10%

Category	Description	Channels
1	**Car2Hotspot** local entertainment/infotainment data	Normal channels (cf. unlicensed 802.11 a/b/g channels)
2	Car2Hotspot Internet Access data	Normal channels (cf. unlicensed 802.11 a/b/g channels)
3	**Car2Car** data concerning vehicle-related comfort functions	
4	Car2Car control data for C2C-CC network management	dedicated C2C-CC channels
5	Car2Car Vehicle Safety Application data	dedicated C2C-CC channels
6	**Car2Roadside** Safety Application data	dedicated C2C-CC channels
7	Car2Roadside toll collect and comfort data	

C2X MAC Layer characteristics

- it encodes packets into bits and vice versa
- it controls access to the wireless medium and permission to transmit data
- its access scheme is the Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)
- it handles errors in the physical layer, flow control and frame synchronization
- the addressing scheme is physical (MAC addresses)

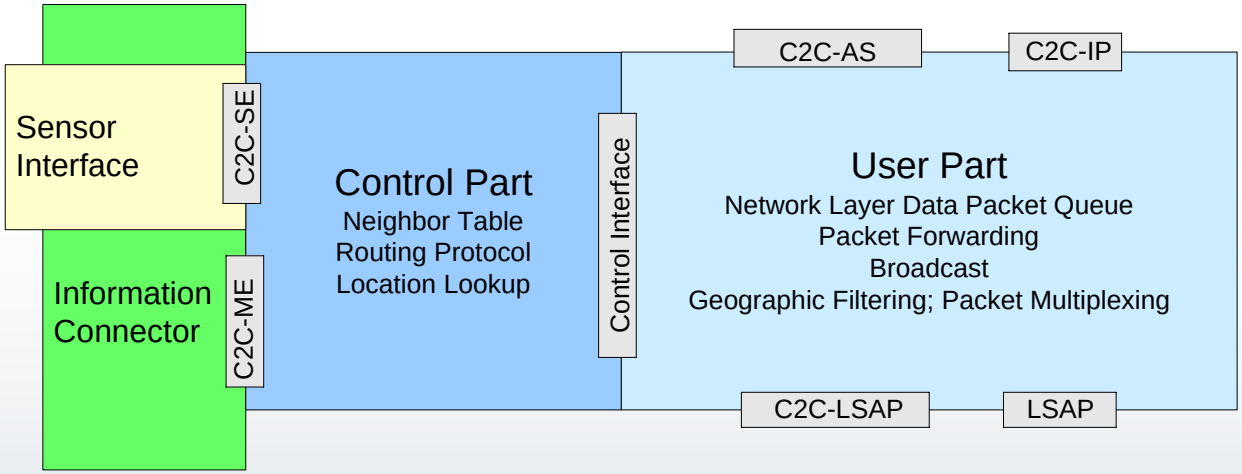
C2X MAC Layer requirements

- Reliable broadcast
- Communication on multiple channels
- Quality of Service
- Transmission power control
- Priority mechanism for different data types, like the 802.11e for its back compatibility with 802.11 family
- a node shall support the concurrent use of 48 bit and 64 bit link layer addresses to achieve compatibility with commercial wireless LAN access technologies
- To guarantee privacy:
  - Each C2C-CC node shall be unambiguously referenced by its link layer address (MAC address) while communicating with other C2CC nodes.
  - A node shall support the use of multiple link layer addresses either sequentially (use one after another) or simultaneously (use at the same time).

C2X NET Layer (C2C-NL) characteristics

- **in general**, it includes routing and forwarding, as well as addressing, interconnecting different networks (internetworking), error handling, congestion control, and packet sequencing.
- provides **wireless multi-hop communications**
- is based on **geographical addressing and routing**
  (broadcast, unicast, anycast)
- provides **beaconing, location-service, and packet forwarding**
  (line- and area-forwarding)
- make use of **positioning capabilities** (from satellite or navigation systems)
- uses different **unicast and broadcast** forwarding schemes
- provides **3 data delivery schemes** :
  area geographical broadcast, single hop broadcast, periodic beacon packets (control plus data)

C2C-NL internal structure



- the **control part** sends **network layer control beacons** and exchange location lookup requests/ answers with other nodes (tables' maintenance)
- the **user part** provides Service Access Points (**SAPs**) to the IP layer and to the geo-addressed application. Its task is to forward data packets in line or area forwarding mode.
- In addition to the physical addressing scheme, C2C-CC-NL supports logical addressing on network layer by two general **address types**:
  - Single universal unique identifier (**UID**); instead of UIDs, unique pseudonyms must be used in exchanging information between C2X-RS nodes
  - **IPv6** Addresses
- A C2X-RS shall support **encapsulating IPv6 packets** within C2C-CC Network Layer packets (tunneling)

C2C-NL components

- Neighbors table, in which the direct neighbors of each car are registered.
  - used for routing algorithms
  - updated by receiving network layer control beacons from direct neighbors (or by extracting neighbors' information from received data packets)
  - is mandatory and is included in the network layer beacons

- Location table, where locations of other nodes are stored
  - positions and the times when these positions were recorded, extracted from received data and control packets
  - is mandatory and queried when routing needs locations

C2X Congestion Control

- **2 initial proposals**:
  - **a cross-layer congestion control** was proposed:
    - use different queues for different priorities
    - perform channel usage evaluation for reserving “safety bandwidth”
    - control non-safety and comfort traffic at PHY/MAC/NET layers
  - a **simpler scheme** was also suggested:
    - relevance of message is determined by receiver/forwarder
    - relevance expressed by single priority value
    - communication system utilizes priority for congestion control
- **recently proposed**
  - **MAC layer solution**: allows a client residing in an upper layer or a control plane to manage medium congestion by providing derived MAC/PHY measures and providing both manual and automated controls of relevant 802.11 and 802.11e MAC/PHY parameters
  - **cross-layer MAC/NET solution**: power control at MAC layer based on decisions taken at NET layer on power measurement beaconing
  - **NET layer solution**: to time re-broadcasting of multi-hop safety broadcasts, where the algorithm may choose a suitable transmission time from congestion control point of view.

C2X Congestion Control (2)

- **Communication types <u>currently</u> in the C2C CC scope**:
  - Single-hop Periodic Control Broadcast
    (**Example**: neighbor beaconing)
  - Single-hop Periodic Safety Broadcast
    (**Example**: merging assistance)
  - Multi-hop Event driven Safety Broadcast
    (**Example**: emergency warning to out vehicles)
  - Multi-hop Event driven Non-safety Unicast
    (**Example**: access router binding update)
  - Multi-hop Periodic Non-safety Unicast
    (**Example**: internet based driver assistant services)
- **Communication types for <u>future</u> extension to Car-2-Car CC scope**:
  - Single-hop Periodic Safety Point-to-point Messaging
    (**Example**: platooning)
  - Multi-hop Event driven Non-safety Broadcast
    (**Example**: traffic management services)

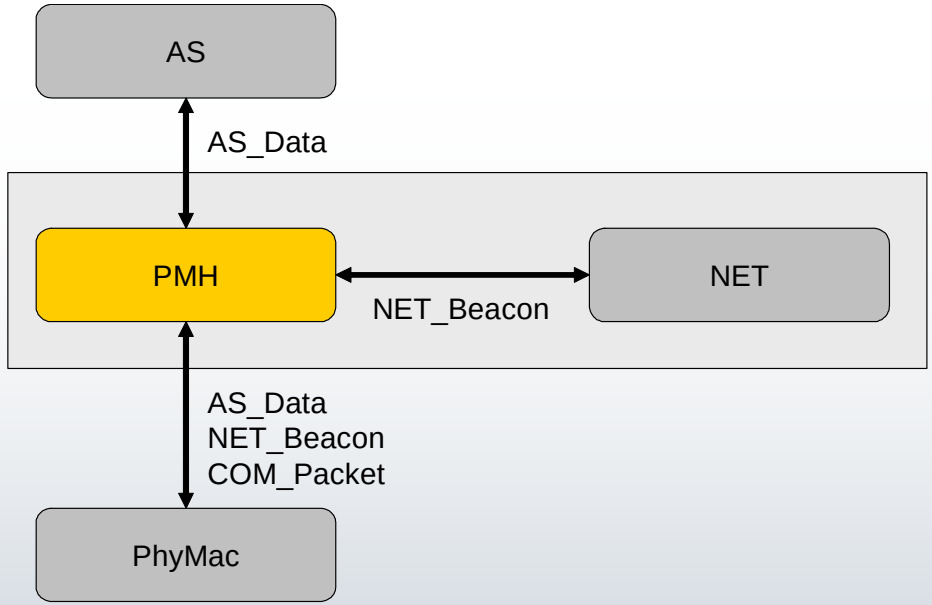
C2X Congestion Control (3)

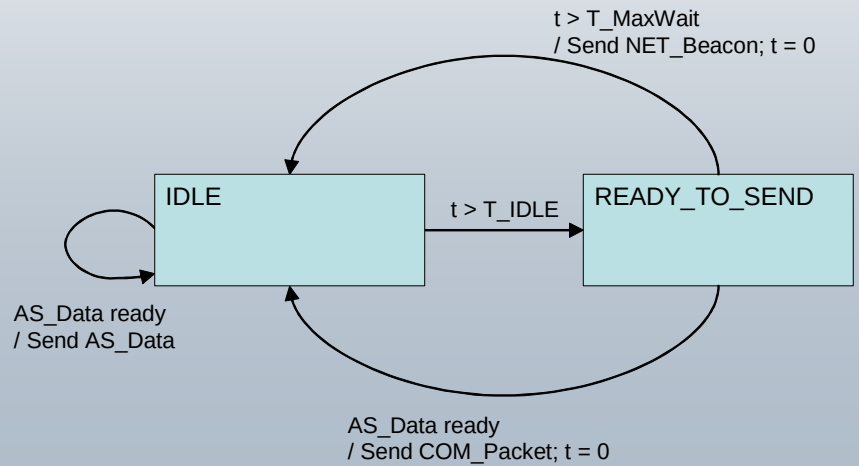
?	Channel Access Restriction	Power Control	Rebroadcast Timing	Efficient Next Forwarder Selection	Multihop Restriction
Single-hop Periodic Control Broadcast	Possibly Useful (for short duration only)	Most Appropriate	Not Applicable	Not Applicable	Not Applicable
Single-hop Periodic Safety Broadcast	Not Applicable	Most Appropriate	Not Applicable	Not Applicable	Not Applicable
Multi-hop Event driven Safety Broadcast	Not Applicable	Not Applicable	Most Appropriate	Not Applicable	Not Applicable
Multi-hop Event driven Non-safety Unicast	Possibly Useful	Possibly Useful	Not Applicable	Most Appropriate	Possibly Useful
Multi-hop Periodic Non-safety Unicast	Possibly Useful	Possibly Useful	Not Applicable	Most Appropriate	Possibly Useful
Single-hop Periodic Safety Point-to-point Messaging	Not Applicable	Most Appropriate	Not Applicable	Not Applicable	Not Applicable
Multi-hop Event driven Non-safety Broadcast	Possibly Useful	Possibly Useful	Most Appropriate	Not Applicable	Possibly Useful

C2C-NL Beacons Workflow

The **Periodic Message Handler** (PMH) has the task of effective and intelligent combining of the information of **AS_Data** and **NET_Beacons** before giving it to the PHYMAC and to extract the required information out of received packets and distribute the parts to NET as well to the AS. **COM_Packets** are merges and not a sums …

t < T_IDLE	AS_Data
T_IDLE < t < T_MaxWait	COM_Packet
T >= T_MaxWait	NET_Beacon





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