# Lecture 30: Physical and MAC Layer in Vehicular Ad-Hoc Networks(VANETs)

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# VANETs

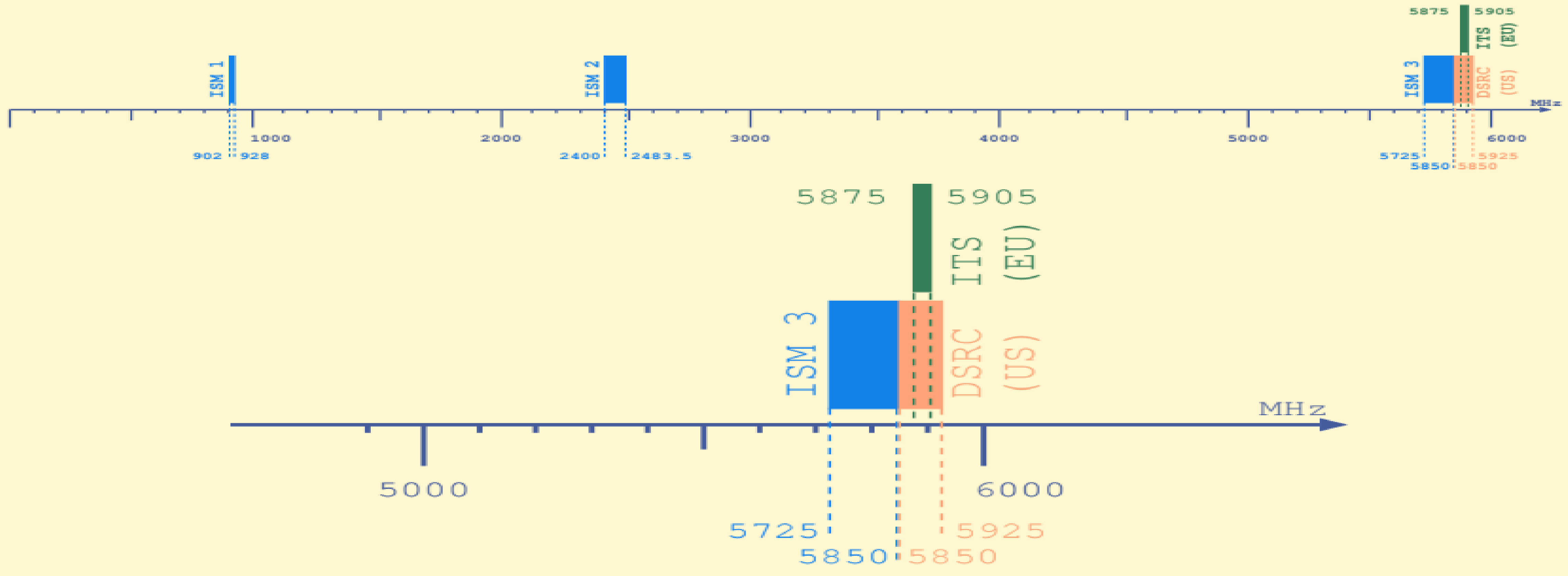
- VANETs are envisaged to provide a communication range **of 1000 meters** with roadside units and other vehicles, at relative speeds up **to 200 km/h,** irrespective of the environment.
- Applications for VANETs can be divided into the following broad categories namely, **safety related, traffic management and transportation efficiency**, user infotainment services and Internet connectivity.
- Safety related applications include **lane change assistance, cooperative forward incident warning, intersection collision avoidance, emergency or incident warning.**
- Traffic management applications form part of a **greater Intelligent Transportation System (ITS) and include toll collection, intersection management, cooperative adaptive cruise control, and detour or delay warning.**

# PHY Layer

- IEEE 802.11p
- Frequencies
  - DSRC band 5.9 GHz
    Dedicated Short Range Communications
  - Not the same band in USA, Europe and Japan
- Channel sharing
  - Code Division Multiple Access
  - $\in$ IEEE 802.11
- Modulation
  - OFDM
    Orthogonal Frequency Division Multiplexing
  - Adaptation to be more robust to Doppler and mutlipath

# DSRC Frequencies

- DSRC: Dynamic Short Range Communications
  Not the same signification in US and EU
- ITS: Intelligent Transportation Systems



# From 802.11a to 802.11p

- Channels of 5, 10 and 20 MHz instead of 20 MHz:
  - Doppler spread up to 2 kHz fast moving nodes
  - RMS delay spread up to 0.8 $\mu$s multipath
  - 20 MHz channel in 802.11a $\rightsquigarrow$ guard of 0.8 $\mu$s
  - Guard interval of 1.6 $\mu$s instead of 0.8 $\mu$s
    Larger than the measured delay spread
    Inter-Symbol Interference reduced (ISI)
  - Doppler effect much smaller than half the subcarrier separation distance (156.25 kHz)
    Inter-Carrier Interferences (ICI) reduced
  - Duration of a symbol doubled (6.4 $\mu$s)
    The channel estimation performed during preamble reception may become invalid at the end of the frame $\rightsquigarrow$ advanced receiver or specific OFDM

# Physical Layer Challenges

# Doppler Effect

- Another challenge caused by the **mobile nature of vehicles** is the **Doppler Effect.**
- If a **vehicle transmitting an RF signal** is moving at high speed relative to a receiving vehicle**, the received frequency could differ from the transmitted frequency by as much as 300 Hz.**
- This is called the Doppler Effect and can also be observed by the change in audible frequency when a vehicle with a siren passes by. In order to correctly receive and interpret the transmitted information, the receiving vehicle has to compensate for the change in frequency.

# Multipath fading

- When a radio wave follows more than one route to get from a transmitter at point A to a receiver at point B, there is a chance that the signal will experience positive or negative interference at point B due to the difference in traveling time along the different routes.
- Negative interference reduces the **signal level** and positive interference increases the signal level, which results in a varying signal at the receiver.

- This is referred to as multipath fading and is due to the mobile nature of VANETs, the varying levels of *multipath fading* is a significant challenge [29][96]. Other physical layer challenges include adjacent channel interference and interference from other RF sources (e.g. WiFi).

# Interferences

- A further challenge introduced by high mobility is the unpredictable and varying nature of the transmission medium.
- As vehicles move relative to each other and objects, such as buildings, pedestrians or trees, the physical properties of the link are continually perturbed.

# Recent VANET Research Areas

| **VANET Topic** | **IEEE Xplore publications** |
|---|---|
| Broadcasting | 646 |
| Routing | 253 |
| Evaluation of existing wireless technologies (cellular, Wi-Fi and WiMAX) | 98 |
| Security | 153 |
| ***Medium Access Control (MAC)*** | ***38*** |

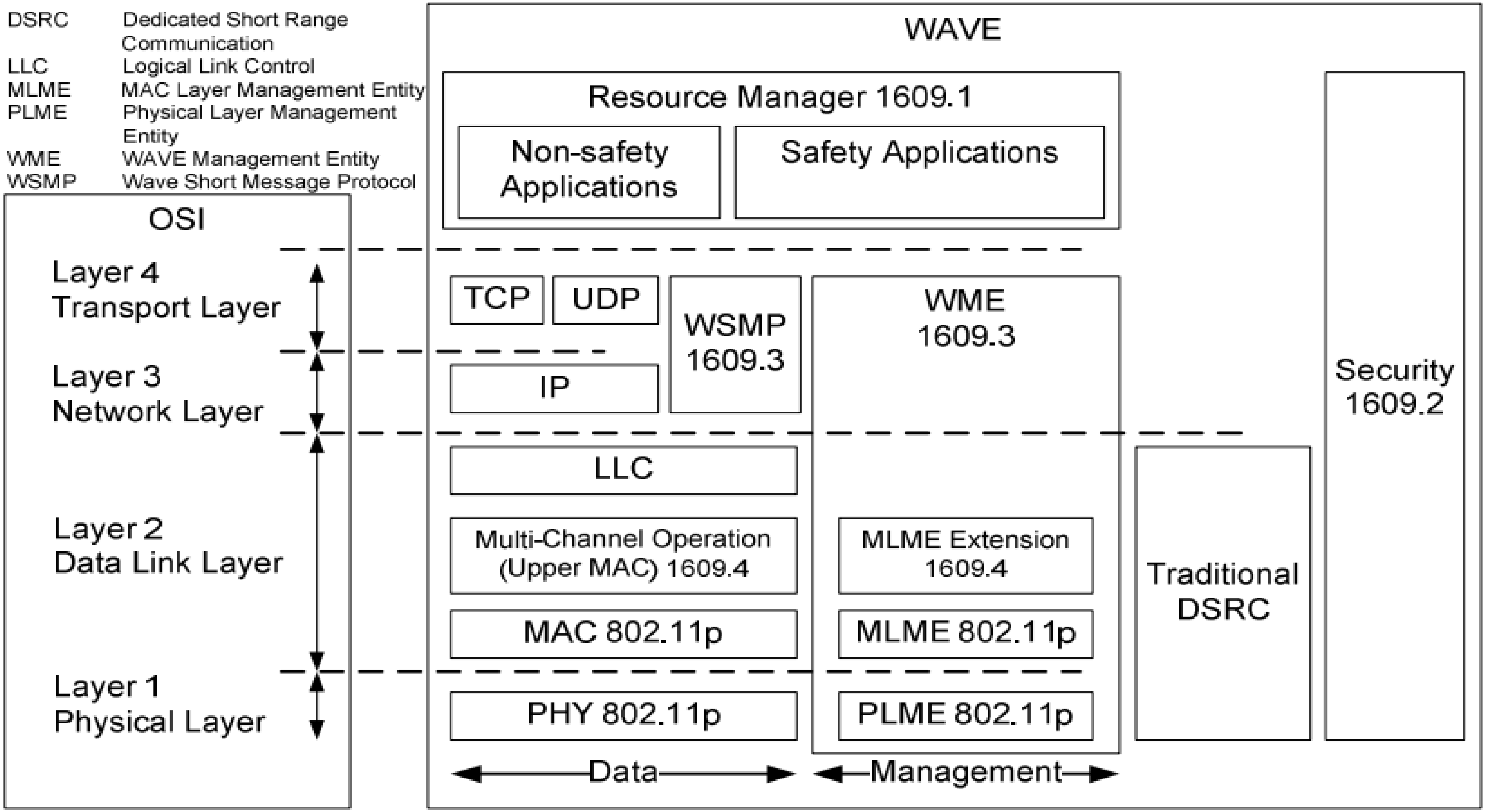
# Common Performance Metrics used for Evaluating MAC Methods

| Performance Metric | Description of Performance Metric | Reference |
| --- | --- | --- |
| *Maximum medium access delay* | Measures how long a node has to wait to get access to the medium. | [27][28] |
| *Payload delivery delay* | Measures the time it takes to send either a packet or multiple packets from one point in the network to another. This metric could also include a measure of the time for a round trip. | [26][27][25] |
| *Throughput (or goodput)* | Measures the data transmitted from one point in the network to another in a given time. When goodput is measured, only the effective data throughput is measured, excluding management and overhead. | [27][25][31] |
| *Overhead* | Measures the ratio of data transmitted to manage or maintain the network, as opposed to goodput. | [26] |
| *Fairness of access (Index of)* | An index is used to measure fairness of access. The concept depends on the definition of fairness. Karamad et al. [1] based fairness on the premise that all nodes, despite their speed, should be able to send the same number of messages to an RSU in a given time. The faster moving nodes must therefore get more chance to transmit. The fairness metric in [1] measures the likelihood for each node to transmit relative to its speed. | [29] |
| *Probability (or ratio) of successful delivery* | Measures the probability of messages (especially safety messages) being successfully delivered. | [29][26][32][33] |
| *Network stabilization time* | Time it takes for all nodes to be allocated a transmission slot and for the network to reach a stable state. | [25][33] |

# IEEE standards for VANETs

| IEEE std. | Purpose and function |
|---|---|
| 1609.1 | WAVE resource manager |
| 1609.2 | Security, secure message formatting, processing and message exchange |
| 1609.3 | Routing and transport (networking) services (alternative to IPv6). Provides management information base for the protocol stack |
| 1609.4 | Multiple-channel operation in the DSRC standard, supplementing the IEEE 802.11p |
| 802.11p | Specification for the physical and MAC layer to enable operation in the WAVE (highly mobile nodes), based on 802.11a |

# IEEE VANET standards



# MAC DESIGN CONSIDERATIONS FOR VANET

- A unique characteristic of VANET that distinguishes it from other ad hoc networks is the high mobility of nodes (vehicles).
- Limited connections currently exist between vehicles and different types of infrastructure, such as the Internet and toll collection facilities.
- Whenever an occupant of a vehicle carries a mobile phone with a data connection to a cellular service, the user can access the Internet from within the vehicle.
- Newer vehicles are equipped with built-in mobile phone connectivity that enables various Internet-based services to occupants. These connections are, however, limited to Internet connectivity.

# MAC in VANETs

- As was mentioned earlier, one of the greatest challenges in making VANET a *cost-effective* technology that can be easily deployed and adopted, is the time it takes to establish connections between vehicles (nodes) and other vehicles, or between vehicles and RSUs, as well as the delays incurred during the management of access to the underlying wireless medium.
- The problem is most noticeable in the scenario where two cars travel in opposite directions at speed, attempt to establish a connection, and need to transfer information on a constantly changing medium, while managing the medium and accompanying data collisions.
- The bottleneck in this process is the Medium Access Control (MAC) layer . This was also demonstrated to be the case for IEEE 802.11p. Several design challenges still need to be addressed at the MAC level to achieve fast, reliable, and fair access — these challenges are discussed in the next section.

# MAC Design Challenges for VANET

- The *hidden terminal* problem where two nodes are outside of each other's range, but both attempt to communicate with a node that is within the range of both.
- This problem is likely in pure V2V environments where there is no centralized communication coordination.
- The result of the hidden terminal problem is message collisions.

# The hidden terminal problem