Lecture 1-2: Vehicular Ad-Hoc Networks(VANETs)

Dr. Debasis Das
Department of CSE
IIT Jodhpur,Rajasthan, India.

Vehicular Ad Hoc Network (VANET)

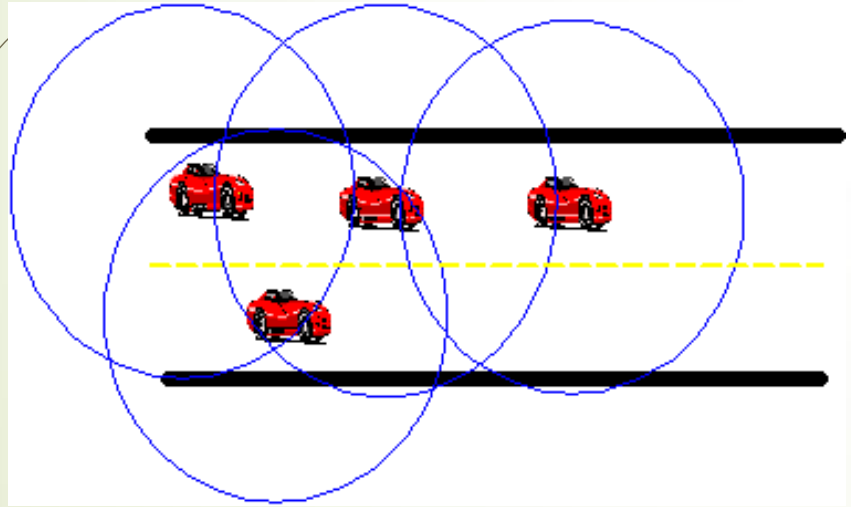
- Ad-Hoc Network:
  - A network with minimal or no infrastructure
  - Self-organizing
  - Each node can act as the source of data, the destination for data and a network router
- *Vehicular Ad Hoc network* (VANET)
  - Uses equipped vehicles as the network nodes
  - Nodes move at will relative to each other but within the constraints of the road infrastructure

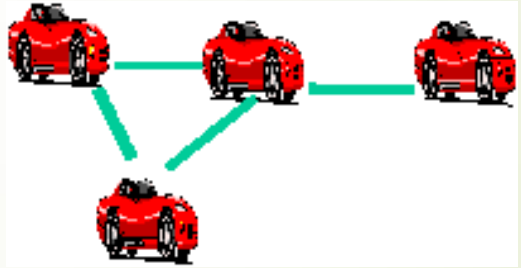
Differences VANETs from MANETs

- Rapid Topology Changes
  - High relative speed of vehicles => short link life
- Frequent Fragmentation
  - Chunks of the net are unable to reach nodes in nearby regions
- Small Effective Network Diameter
  - A path may cease to exist almost as quickly as it was discovered (reactive routing)
- Limited Redundancy
  - The redundancy in MANETs is critical to providing additional bandwidth
  - In VANETs the redundancy is limited both in time and in function

Vehicular Ad Hoc Network (VANET)

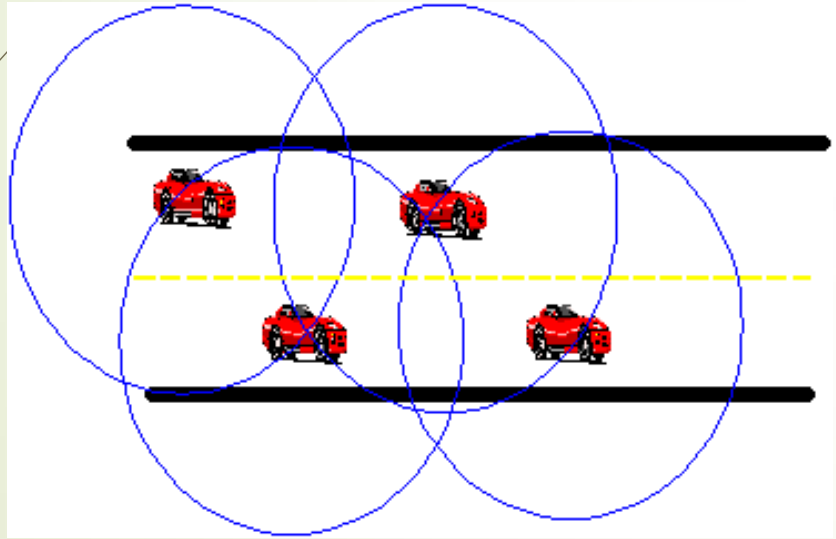
- Message propagates to destination using a number of intermediate links

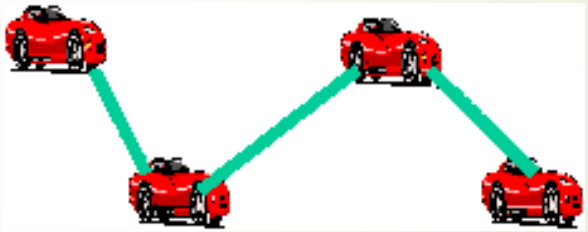




Vehicular Ad Hoc Network (VANET)

- If vehicle mobility causes links to break, message rerouted using a different path

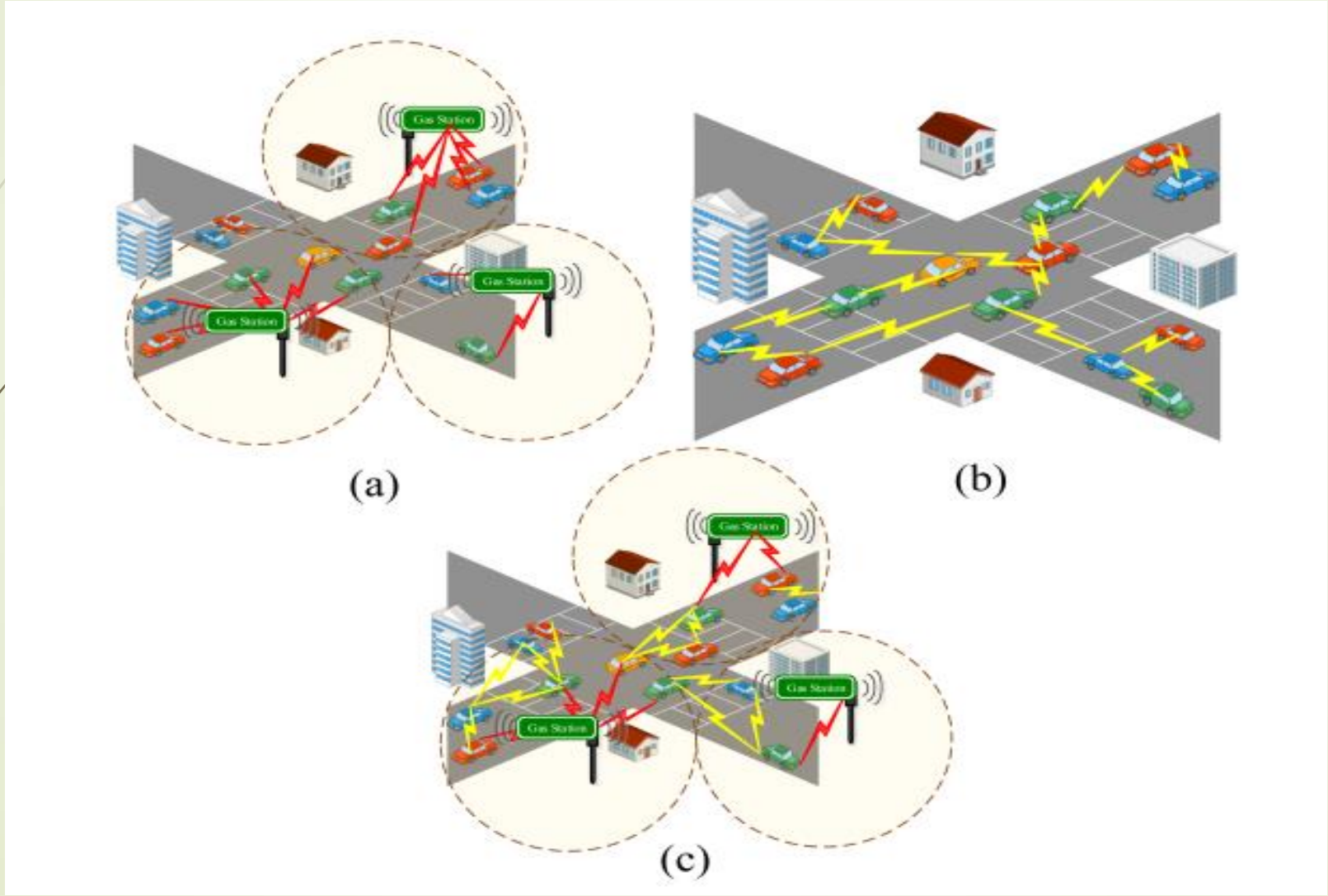




Why use *VANETS*?

- Easier deployment
  - Decreased dependency on fixed infrastructure
- Sparse network of roadside beacons
- Permit gradual introduction of technology
- Location-oriented services can be provided with little or no running costs to the users

The communication architectures of VANETs: (a) WAVE base Wi-Fi; (b) Adhoc; (c) Hybrid



Requirements on vehicular communication

- Mobility
- Delay bounded (real-time)
- Scalability
- Bandwidth efficiency
- Cost
- Fairness
- Any time, any place, any hosts (GPS unequipped vehicles, standardization between cars' manufactures)

Addressing the challenges

- Physical Layer
  - limited bandwidth
- Link Layer
  - congestion control, latency, throughput, fairness and scalability
- Network (Routing) Layer
  - rapid topology changes and network fragmentation

DSRC – Operating Characteristics

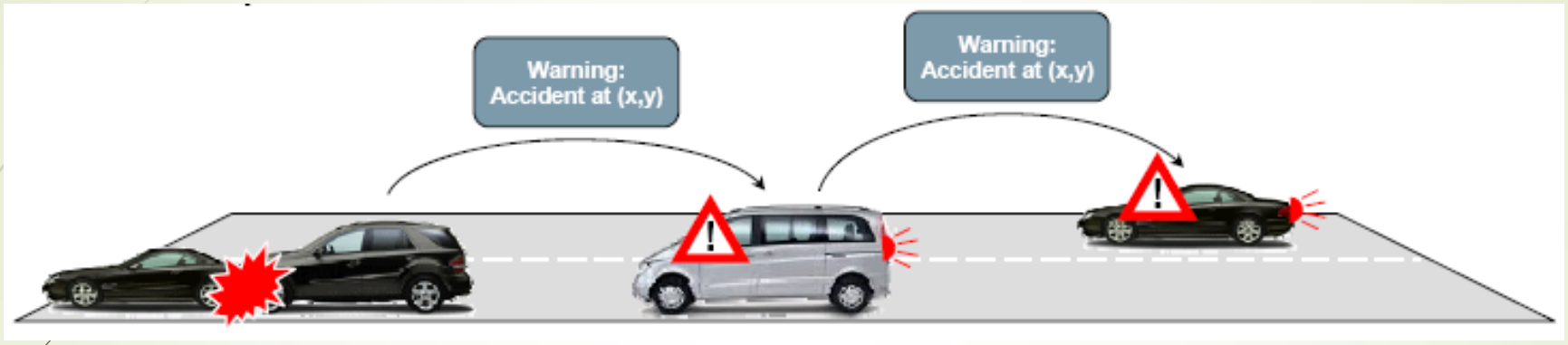
- IEEE 802.11p protocol (802.11a modification for VC)
- Maximum range: 1000 m
- Vehicle speeds up to 100 mph
- Low latency: 50 ms

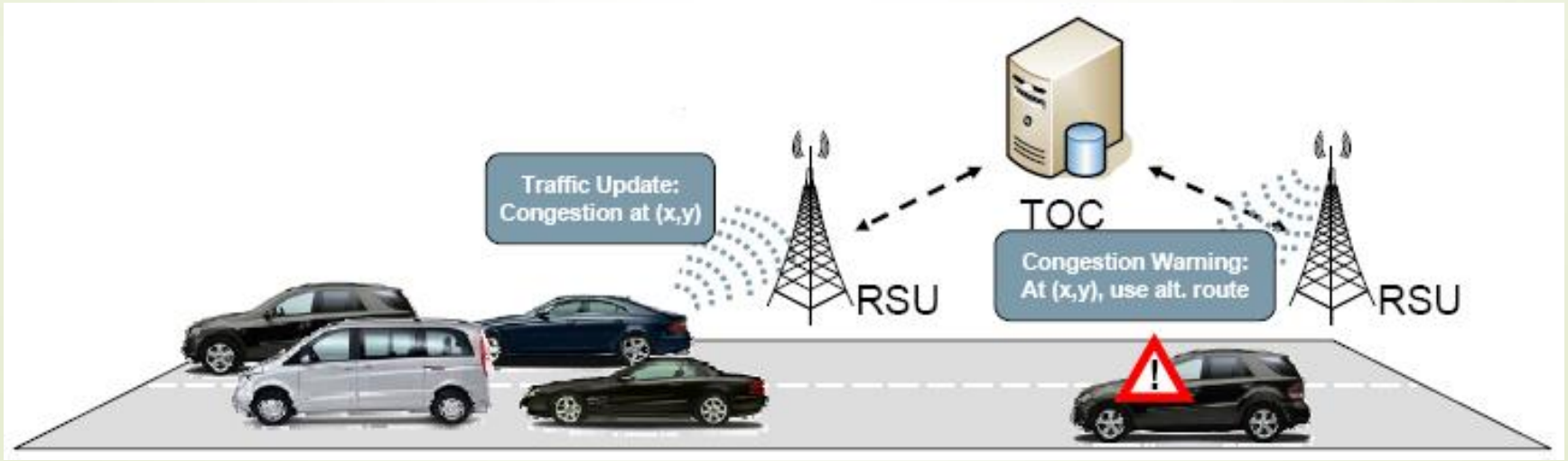
Routing Protocols

- Reactive protocols
  - Determine route if and when needed
  - Source initiates route discovery
  - Example:
  - DSR (Dynamic Source Routing)
  - AODV (Ad hoc On-Demand Distance Vector)
- Proactive protocols
  - Traditional distributed shortest-path protocols
  - Maintain routes between every host pair at all times
  - Based on periodic updates; High routing overhead
  - Example: DSDV (destination sequenced distance vector)
  - Optimized Link State Routing (OLSR)
- Hybrid protocols
  - Adaptive; Combination of proactive and reactive
  - Example : ZRP (zone routing protocol)

Vehicle Communication (VC)

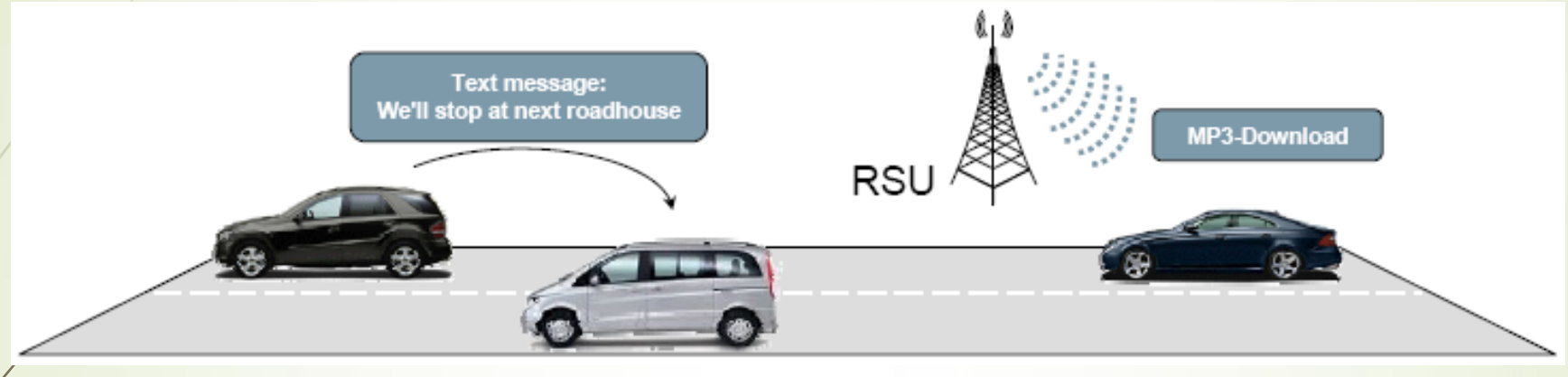
- VC promises safer roads,

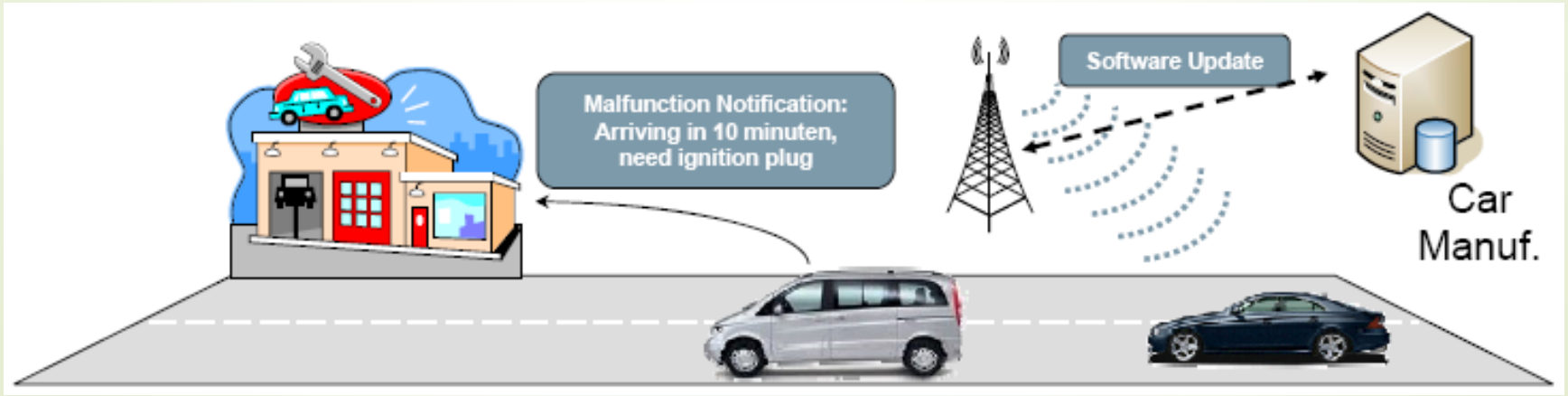




Vehicle Communication (VC)

- … more fun,





Intelligent Transport System (ITS)

- Advanced vehicles and associated transportation infrastructures that use IT&C technology to make driving safer, efficient and comfortable
- Operation of vehicles, manage vehicle traffic, assist drivers with safety and other information, provisioning of convenience applications for passengers
- ITS
  - high interest for companies, operators, government, academia, research; many countries have public and private sector bodies working on ITS
  - Important technologies - implementing many applications related to vehicles, vehicle traffic, drivers, passengers and pedestrians
- **Typical use cases and services/applications**
  - **Active road safety** applications
    - Warnings, notifications, assistance
  - **Traffic efficiency** and management applications
  - **Infotainment** applications

Intelligent Transport System (ITS)

- **Typical use cases and services/applications**
  - **Active road safety applications**
    - Collision warning: Intersection, Risk, Head on, Rear end, Co-operative forward, Pre-crash
    - Warning on: Overtaking vehicle, Wrong way driving, Stationary vehicle, Traffic condition, Signal violation, Control Loss, Emergency vehicle proximity, etc.
    - Lane change assistance
    - Emergency electronic brake lights
    - Hazardous location notification
    - Co-operative merging assistance

    - **Message types for safety apps**: time-triggered position messages and event-driven hazard warnings

  - **Traffic efficiency and management applications**
    - Speed management and Co-operative navigation
  - **Infotainment applications**
    - Co-operative local services
    - Global Internet services

Intelligent Transport Systems (ITS)

- Many **projects and standards** - developed all over the world: USA, Europe, Asia, etc.
- Standardization made by US Federal Communications Communication (FCC)
  - allocation of 75MHz of ***Dedicated Short Range Communication (DSRC)*** spectrum
  - basically for V2V and V2I communications for safety apps.

- Numerous research works and standardization/projects have been performed
- **Examples:**
  - **DSRC** development by Vehicle Safety Communications Consortium (VSCC) (USA)
  - European automotive industry project dedicated to road safety development and demo - **PReVENT** project (Europe) 2004-2008
  - Internet intelligent transportation system (ITS) **Consortium and Advanced Safety Vehicle** project (Japan), 2011-2015
  - **Car-2-Car** Communications Consortium (C2C-CC), ETSI TC ITS
  - **Vehicle Infrastructure Integration** (VII) Program- USA 2009
  - Secure Vehicle Communication (**SeVeCOM**) - FP6 Europe, 2006-2008
  - **Network on Wheels** project (Germany), 2008, etc.

Vehicular Communication Technologies

- ***DSRC (Dedicated Short Range Communication):***
  - Related to the spectrum dedicated to vehicular communication and any type of communication among ITS components (vehicles, infrastructure)
  - US *Federal Communications Commission* (FCC) allocated 75 MHz of spectrum in the 5.9 GHz band for ITS - 1999
  - ETSI allocated 30 MHz of spectrum in the 5.9 GHz band for ITS - 2008

  - **Issue:** DSRC systems in Europe, Japan and U.S. are not fully compatible and include some significant variations (5.8 GHz, 5.9 GHz or even infrared, different baud rates, and different protocols).

- ***WAVE (Wireless Access in Vehicular Environment):***
  - basically is related to all MAC/PHY protocols and standards used for vehicular communication (DSRC)
  - it mainly defines MAC/PHY protocols
  - however, the higher layers, such as IEEE 1609.1-4, are also considered in WAVE

  - **WAVE : IEEE 802.11p + IEEE 1609.1-4 + SAE 2735** (*Society of Automotive Engineers*)

Vehicular Communication Technologies

- **VANET**
  - V2V and V2I communications based on WLANs
  - Features
    - Special applications (e.g., collision warning and local traffic information for drivers)
    - resources (licensed spectrum, rechargeable power source)
    - environment (e.g., vehicular traffic flow patterns, privacy concerns)

- **VANET Applications examples**
- **Safety**
  - Severe delay tolerance (~100ms); Purpose: avoid collisions and accidents
- **Non safety**
  - Efficiency/traffic management
    - Latency – few seconds; Purpose: save time and money
  - Comfort
    - Relaxed latency constraints; Purpose: info on facilities- restaurants, hotels, parking, etc.
  - Entertainment
    - Real-time or non-real time constraints (depending on apps.)
    - Multimedia sharing, general Internet access, etc.

VANET **characteristics**

- **Commercial, objectives, architecture**
  1. Architecture supports specific apps. only (safety, traffic efficiency)
  2. Internet access is not fully available (due to specific architecture)
- **Collaboration capabilities:**
  1. specific architecture, non-collaborative (i.e., Internet-wide)
- **Communication types:**
  1. basically - V2V, V2R, only partially V2I
- **Processing power and decision capabilities:**
  1. limited (local simple decisions), low volume data
- **Compatibility with personal devices**:
  1. limited

VANET **characteristics**

- **Scalability:**
  non-scalable (consequence of its architecture)
- **Connectivity:**
  VANET: vehicles can experience connection/disconnection- depending on network current availability
- **Network/environment awareness:**
  VANET: limited (basically on neighborhood of the vehicle)
- **Cloud Computing (CC) compatibility**:
  VANET: limited (possible, but currently not supported)

Main VANET characteristics

Characteristic	VANET
Participating nodes	Vehicles (OBU) , Roadside unit (RSU) static and/or mobile nodes
Communication type	V2V, V2R/V2I, single or multi-hop
Available bandwidth	e.g. 75MHz band available for VANET in US
Energy constraint	No
Topology	Variable: nodes (vehicles) frequently join and leave the network Vehicle movements – may be correlated
Node mobility speed	0 – 40 m per second
Signal reception quality	Poor signal reception due to the radio: obstacles, (roadside buildings) interferences
Connection life	Short- depending on road conditions, traffic lights, jams, etc.
Physical Channel	Fast time varying (blocked transmission by buildings, vehicles)
Connectivity	End-to-end connectivity not guaranteed
Additional sensors	High-quality GPS and digital maps
Infrastructure	RSUs work as gateways to the Internet

Application categories

- **Infrastructure oriented applications**
  - management optimization: transit, freeway, intermodal freight
  - emergency organization...
- **Vehicle oriented applications**
  - road safety
  - incident management, crash prevention, collision
  - avoidance, driver assistance...
  - automatic/adaptive settings
- **Driver oriented services**
  - improving the road usage
  - traffic jam, road work information, traveller
  - payment, ride duration estimate...
- **Passengers oriented applications**
  - for offering new services on board
  - Internet access, distributed games, chats, tourist information
  - city leisure information, movies announces downloads

ITS ad-hoc network

- Essentially is an ad-hoc V2V, connecting also roadside and personal ITS stations
- Wireless technologies (limited range)
- Stations mobility → arbitrary network topologies, without the need for a coordinating communication infrastructure
- Example: network of vehicle, roadside and personal ITS stations interconnected

Basic VANET system components

- **RSU- Road Side Unit**
- **OBU On-board Unit**
- **AU - Application Unit**

- Typically
  - RSU hosts applications that provides services
  - OBU is a peer device that uses the services
- The applications may reside in the RSU or in the OBU (provider/user model)

  - OBU
    - set of sensors *to collect* and *process* the information
    - sending information as messages to other Vs or RSUs

  - Vehicle: may host n≥1 AUs that use the applications offered by the provider, supported by OBU connection capabilities

- The RSU can also connect to the Internet or to another server which allows AU's from multiple vehicles to connect to the Internet

Basic VANET system components

- **On-Board Unit (OBU)** *(Ref [13] Saini)*
  - HW device mounted on the vehicle
  - It communicates with other OBUs and RSUs (~router)
  - **Typical structure**:
    - transceiver, RF antenna
    - processor
    - read/write memory
    - user interface
    - A *Vehicle Control Unit (VCU)* coordinates with the OBU to collect/disseminate vehicular statistics.
    - Other OBU I/Fs: (e.g. USB and Bluetooth), to connect to other devices on the vehicle, for example: laptops, smartphones and PDAs
    - GPS sensor
  - A **network stack** runs on the processor to provide the abstraction of VANET
  - Communication standards: IEEE 802.11p, IEEE1609.1, 2, 3 and 4

Basic VANET system components

- **OBU basic requirements and responsibilities :**
  - A RF antenna + wireless channel (communication -other OBUs and RSUs)
  - Software to run a specific VANET network stack
  - Data forwarding on behalf of other OBUs

  - **Control functions**:
    - routing, network congestion, control, data security, and IP mobility
  - A user I/F to exchange information with the end user, or a connection with a devic that has a user I/F
  - A mechanism to generate safety messages to be shared with other OBUs and RSUs
    - these messages can come
      - directly from the user
      - or from automatic processing of sensory data

Basic VANET system components

- **RSU- Road Side Unit**
  - antenna, processor, and read/write memory
  - wireless and wired I/Fs to communicate with OBUs, other RSUs and the Internet
  - It can extends the coverage area of OBUs through data forwarding
  - **RSUs are installed** (optimization multi-criteria problem!)
    - along the roads, mainly near intersections and gas stations
    - locations of high vehicle density
  - **Main functionalities of an RSU**
    - RF , high power, and long-range antenna
    - Support access to wired channels, (coax, cable or optical fiber cable, with Ethernet-like protocols)
    - Network stack to run a VANET specific network, link and L1 protocols
    - Forwarding data packets to OBUs in its range and other RSUs
    - Aggregation of safety information from OBUs through safety applications and alarming incoming OBUs
    - GW to provide Internet connectivity to OBUs
  - **Standards to be supported:** IEEE 802.11p, and all four IEEE 1609 protocols

Comparison of wireless technologies for vehicular communication

Characteristic	Bluetooth	Wi-Fi	WAVE	UMTS[1]	LTE[2]	LTE-A[3]
Channel width	1MHz	20MHZ	10MHz	5MHz	1-4-20MHz	Up to 100MHz
Frequency Bands	2.4GHz	2.4GHz, 5.2GHz	5.86-5.92GHz	700-2600MHz	700-2690MHz	0.45-4.99GHz
Bit rate	800Kbps	6-54Mbps	3-27Mbps	2Mbps	Up to 300Mbps	Up to 1Gbps
Range	up to 30m	Up to 100m	Up to 1km	Up to 10km	Up to 30km	Up to 30km
Coverage	Intermittent	Intermittent	Intermittent	Ubiquitous	Ubiquitous	Ubiquitous
Mobility support	Low	Low	Medium	High	Very high (up to 350km/h)	Very high (up to 350km/h)
Broadcast/ multicast support	Limited support	Native broadcast	Native broadcast	Through MBMS	Through eMBMS	Through eMBMS
Vehicle to vehicle support	Limited, through ad-hoc	Native (ad-hoc)	Native (ad-hoc)	No	No	No

MBMS – Media Broadcast and Multicast System

Recent: D2D

Spectrum Allocation in US , Europe, and Japan

	North America	Europe	Japan
Bandwidth	75MHz (30MHz for safety and 40MHz for general purpose)	50MHz (30MHz for safety and 20MHz for general purpose)	80MHz
Frequency range	5850-5925MHz	5855-5905MHz	5770-5850MHz
Channel classification	Control channel (1), service channel (6)	Control channel (1), service channel (4)	Uplink (7), downlink (7)
Channel bandwidth	10MHz (can be up to 20MHz for general purpose channels)	10MHz	4.4MHz
Bandwidth allocation	30MHz safety, 40MHz general purpose	30MHz safety, 20MHz general purpose	Not specified
Coverage	30m	15 to 20m	1000m
Data transmission rate	3-27Mbps	Uplink/500Kbps, Downlink/250Kbps	1 or 4Mbps
Main standardization bodies	IEEE, SAE International, FCC	ETSI, ISO/CEN, CEPT	ARIB, NPA, MITI, MPT

Radio Access Technologies

- DSRC – IEEE 802.11p -WAVE

- **DSRC** (Dedicated Short Range Communications)- short range wireless technology
  - ASTM Standard E2213-03, based on IEEE 802.11a
  - name of the 5.9 GHz Band allocated for the ITS communications
  - DSRC standards suite is based on multiple cooperating IEEE standards
- **IEEE 802.11p** - includes DSRC
  - based on ASTM Standard E2213-03- developed for vehicular communications

- **WAVE** (Wireless Access in Vehicular Environments)
  - mode of operation used by IEEE 802.11 devices to operate in the DSRC band
  - the core design aspects of DSRC is Wireless Access in Vehicular Networks (WAVE) corresponding to IEEE 1609.1/.2/.3/.4
- **DSRC Devices**
  - IEEE 802.11 systems using the WAVE mode of operation in the DSRC band

- **IEEE P1556**
  - WAVE – IEEE P1609 – Layer 3-7 (OSI)
  - DSRC: EEE 802.11p, ASTM 2213

Security and Privacy

- OBU address randomized: prevents tracking vehicles
- Authenticated RSU application announcements: prevents bogus message to V
- Link level encryption for all messages prevents eavesdropping
-
- Authentication: PKI; US Government is CA


THINK