Introduction to Vehicular Wireless Networks

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Audio/Video recordings of this class lecture are available at:
http://www.cse.wustl.edu/~jain/cse574-24/

Student Questions

Overview

1. Vehicular Ad-Hoc Networks (VANET): Architecture, Applications, Requirements, Routing
2. Dedicated short Range Communication (DSRC) and Wireless Access for Vehicular Environment (WAVE)
   - Spectrum
   - Protocol Components
   - PHY, MAC
   - Products

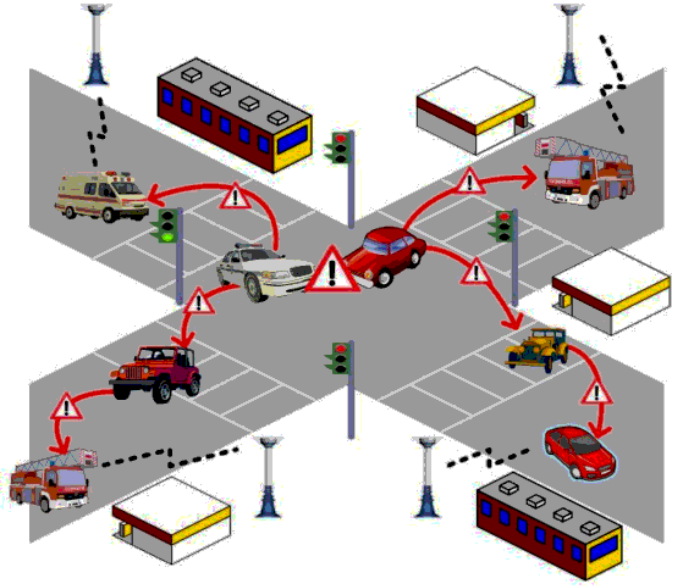
Student Questions

- ❑ Is the WAVE protocol part of the DSRC protocol?

Yes. See Slide 8-11.

Vehicular Ad-Hoc Networks (VANET)

- Dynamic Topology with nodes moving at a fast speed
- More processing power, storage, and energy than handhelds
- Location-based information: Accidents ahead
- Delay constraint
- Varying environments: City streets with tall buildings vs. open high-way roads
- Sensors: GPS, Speed, Proximity, Engine sensor, etc.



Student Questions

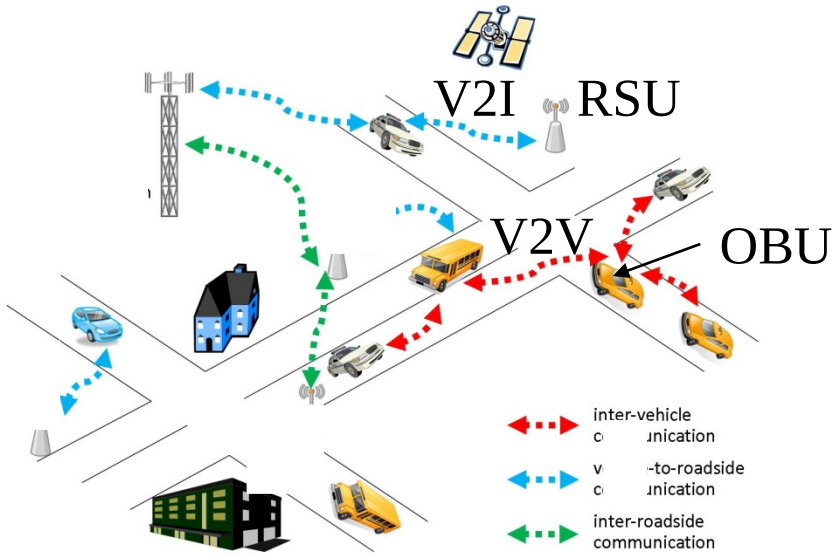
- Are road side units required? Or are they just optional to assist as part of the network?

Some types of communications require RSUs, and others don't. For example, you can't do a Google search without a roadside unit. These types of communications are defined as V2I later.

Ref: Christoph Sommer, Falko Dressler, "Vehicular Networking," Cambridge University Press, November 2014, 384 pp., ISBN:978-1-107-04671-9 (Safari Book).
R. Aquino-Santos, A. Edwards, and V. Rangel-Licea, "Wireless Technologies in Vehicular Ad-Hoc Networks," IGI Global, Feb 2012, 382 pp., ISBN:1466602090 (Not a Safari Book).

VANET Architectures

- Vehicle to Infrastructure (V2I)
- Vehicle to Vehicle (V2V)
- Road-Side Unit (RSU)
- On-Board Unit (OBU)



Ref: R. Aquino-Santos, A. Edwards, and V. Rangel-Licea, "Wireless Technologies in Vehicular Ad-Hoc Networks," IGI Global, Feb 2012, 382 pp., ISBN:1466602090, Safari Book.

Student Questions

- Is VANET intended to only be used between a car and an external device, or could it be used between multiple devices within a single car?

Cars can use and use existing protocols for in-car communications. E.g. Bluetooth, Ethernet.

- To what extent is V2V VANET implemented today? To what extent do cars communicate directly with one another?

It is mostly a concept so far. Some experimental systems exist. Some toll collection systems use DSRC.

- Can you give us some examples of RSU and OBU?

The original idea was to install a dedicated infrastructure, but that did not happen.
RSU = 5G tower, Satellite
OBU = 5G SIM, Satellite receiver
Toyota Sienna 2024 and other cars have "cloud-based navigation," possibly using satellites. Similar to XM Radio.

- Is everything driving on the road called OBU? I mean, how about I ride a bike on the road.

Yes, if you have a VANET unit on the bike.

Applications

- **Infotainment**: Entertainment + Navigation + Telecom
  - Minimize driver distraction: Bluetooth, Voice recognition
- **Traffic Control**: Reduce congestion and fuel consumption
  - Highway advisory radio about congestion
  - Warn before dangerous curves, road conditions
  - Navigation based on congestion
- **Safety**: Car crashes are a major cause of death of children aged five and above.
  - **Adaptive Cruise Control**: Maintain a distance from the vehicle ahead
  - **Forward Collision Warning**: Warn and automatically activate brakes
  - **Speed Regulation**: Maintain the speed limit

Student Questions

- Most of these applications seem like they are contained within a single car, and many of them are already in cars. Are these still considered part of VANET?

Since there are no roadside units, VANET is not being used. Most of these features work based on satellites and local sensors.

Requirements

- **Highly Critical Messages**: Warnings about collision require low delay (20 ms), Electronic Toll collection (50 ms), roadside service locator (500 ms)
- **Non-Critical**: Video entertainment
- **Short Range**: <300 ft
- **Mobility**
- **Security**: Denial of service, Impersonation, Privacy (location, ID, e-payment), tempering (change sensor readings)

Student Questions

Security Requirements

- **Collaboration**: Multi-hop communication
- **Autonomy**: Vehicles should be able to reject participation or a message
- **Authentication**: Originator and/or location
- **Accountability**: Messages that impact network functions should be audited. Deliberate disruption could be penalized.
- **Privacy**: Location, name of the driver, vehicle type, etc. should not be disclosed
- **Availability**: Vehicles should be usable even if the network is down

Student Questions

- This seems like a hot topic right now. What are some things being done to address these security issues?

The usual security mechanisms are implemented after a bug is disclosed.

Routing Types

- **Broadcast**: Traffic, weather, emergency, road conditions, …
- **Geocast**: Within an area. Accidents.
- **Forwarding**: Point-to-point via multi-hop
- **Clustering**: Within a specified group. Police, Fire, Safety,
- **Beaconing**: Periodic exchange of information. Receivers integrate received info with their beacon.
- **Position Based**: Geographical routing based on positions of routers
- **Delay-Tolerant**: Stored and forwarded when another car is seen.
- **Ad-Hoc**: Address-based mobile ad-hoc network routing

Student Questions

- How do we switch between delay-tolerant and regular networks, given different applications?

These are ideas. Not realities. Delay-tolerant routing is used in space by NASA.

- What is the implementation of Geocast? To what extent is an "area" valid?

The broadcaster determines the area, such as your mobile carrier or city administrator.

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Student Questions

❖Could you explain the geographical-based routing vs address-based routing again?

Goegraphical based routing is feasible iff the routers are fixed (not mobile). Then core part of the routing can be fixed. Address based routing allows mobility and can be done at the edges (if core is fixed) or end-to-end if nothing is fixed.

Next Q on 8-14

VANET Technologies

- **Dedicated Short Range Communication (DSRC)**:
  IEEE 802.11p, IEEE 1609.1-4
  Up to 1km at 200 km/h
- **WiMAX**: Better for long distances. V2I
- **3G**: Seamless handoff, high latency
- **Satellite**: Ubiquitous. High Cost. Large propagation delay.

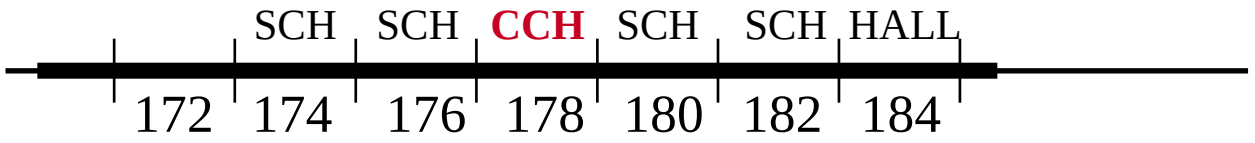
Student Questions

- What other applications are available for 802.11p besides VANET?

It is designed for VANET. However, it is not being used because of the lack of infrastructure. There are no other applications. See note on the next slide.

DSRC Spectrum

- Dedicated short-range communications (DSRC) band allocated by FCC: 5.850-5.925 GHz
- Seven 10 MHz channels in the 5.9 GHz band
- Channel 178 used as **Control Channel (CCH)**
- Channels 174, 176, 180, and 182 used as **service channels (SCH)**
- Channel 184 is reserved for future High Availability Low Latency (HALL)
- Channel 172 is unused
- Different EIRP for 4 Classes:
  OBU:33 dBm, RSU: 43dBm (Govt), 33 dBm (others)



- Due to lack of adoption, the FCC has reallocated all of DSRC's spectrum. 45 MHz to 5.8 GHz ISM band and 30 MHz to Cellular V2X.

Ref: Y. L. Morgan, "Notes on DSRC & WAVE Standards Suite: Its Architecture, Design and Characteristics," IEEE Communications Surveys and Tutorials, Vol 12, No. 4, 2010, pp. 504-518, https://ieeexplore.ieee.org/arnumber=5462975

Student Questions

- Why is channel 172/173 unused?

Don't really know. Som possible answers:

- *Reserved for future use.*
- *Not available in most countries.*
- *Excessive interference with some existing application*

- 4 Classes: OBU, RSU, 33 dBm. There are only three classes?

These are devices, not classes. Each device can have four classes, like IEEE 802.11e.

- Is channel 184 referred to as "high availability low latency" only because it is typically not used under normal circumstances?

Yes, in future it will be typically used for short infrequent messages.

- Why is Channel 172 unused, and what is its potential future use?

It may be used in the future.

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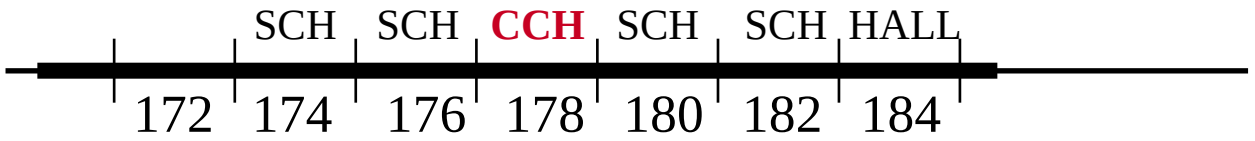


- Due to lack of adoption, the FCC has reallocated all of DSRC's spectrum. 45 MHz to 5.8 GHz ISM band and 30 MHz to Cellular V2X.

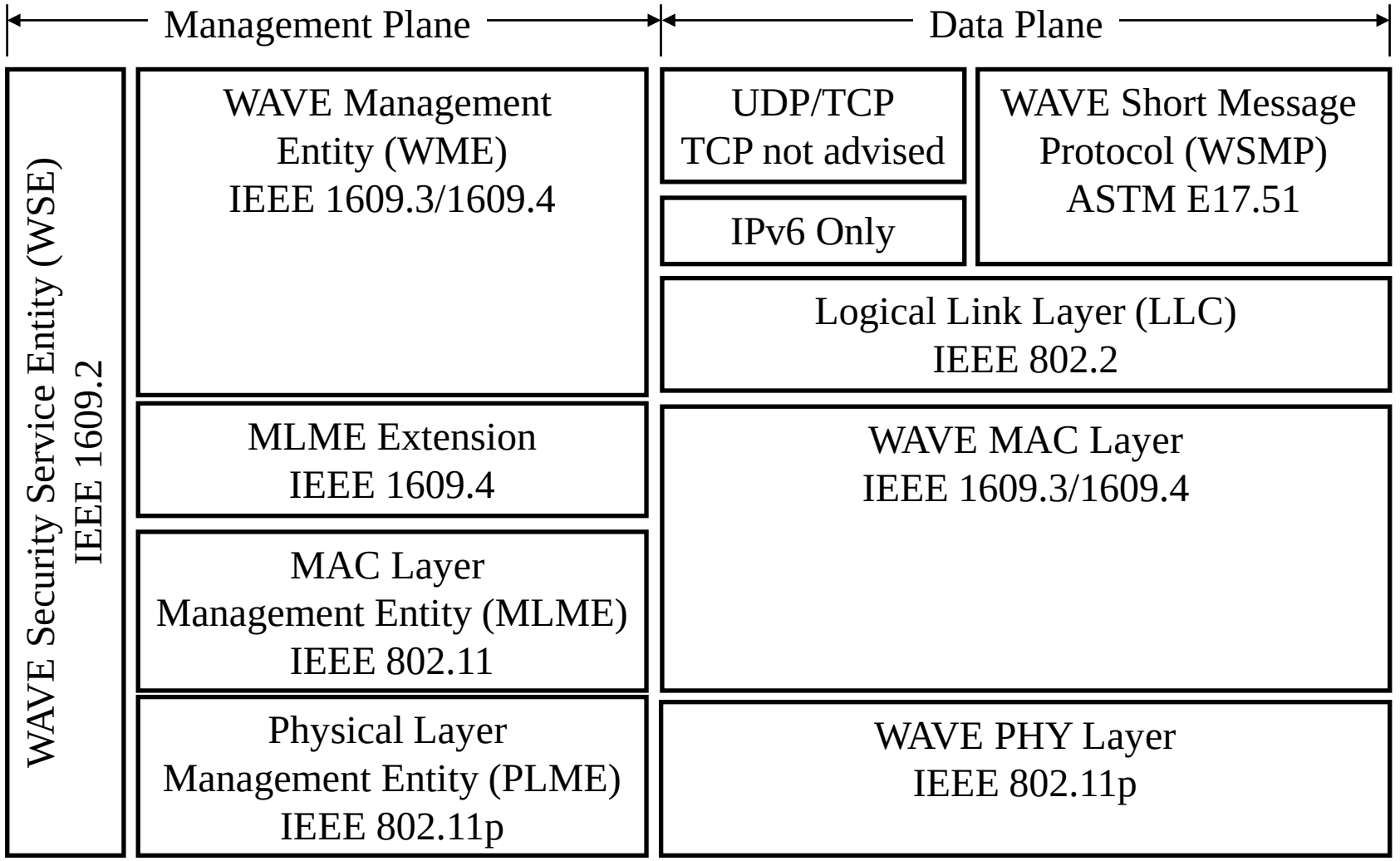
Student Questions

- What are the impacts of the FCC reallocating the DSRC spectrum?

They are used by cell companies using their infrastructure.

Ref: Y. L. Morgan, "Notes on DSRC & WAVE Standards Suite: Its Architecture, Design and Characteristics," IEEE Communications Surveys and Tutorials, Vol 12, No. 4, 2010, pp. 504-518, https://ieeexplore.ieee.org/arnumber=5462975

DSRC Protocol Components



Student Questions

- ❑ Can you mention which parts of this diagram are IPv6 and which are IPv4?

No IPv4 because of address issues. IPv6 is used only in that one part indicated.

- ❑ Will any communication be either on the management plane or on the data plane?

Four planes: Data, Control, Management, and Service. Covered in CSE473 Software Defined Networking Module.
http://www.cse.wustl.edu/~jain/cse473-22/i_4nld.htm (Slide 4-46)

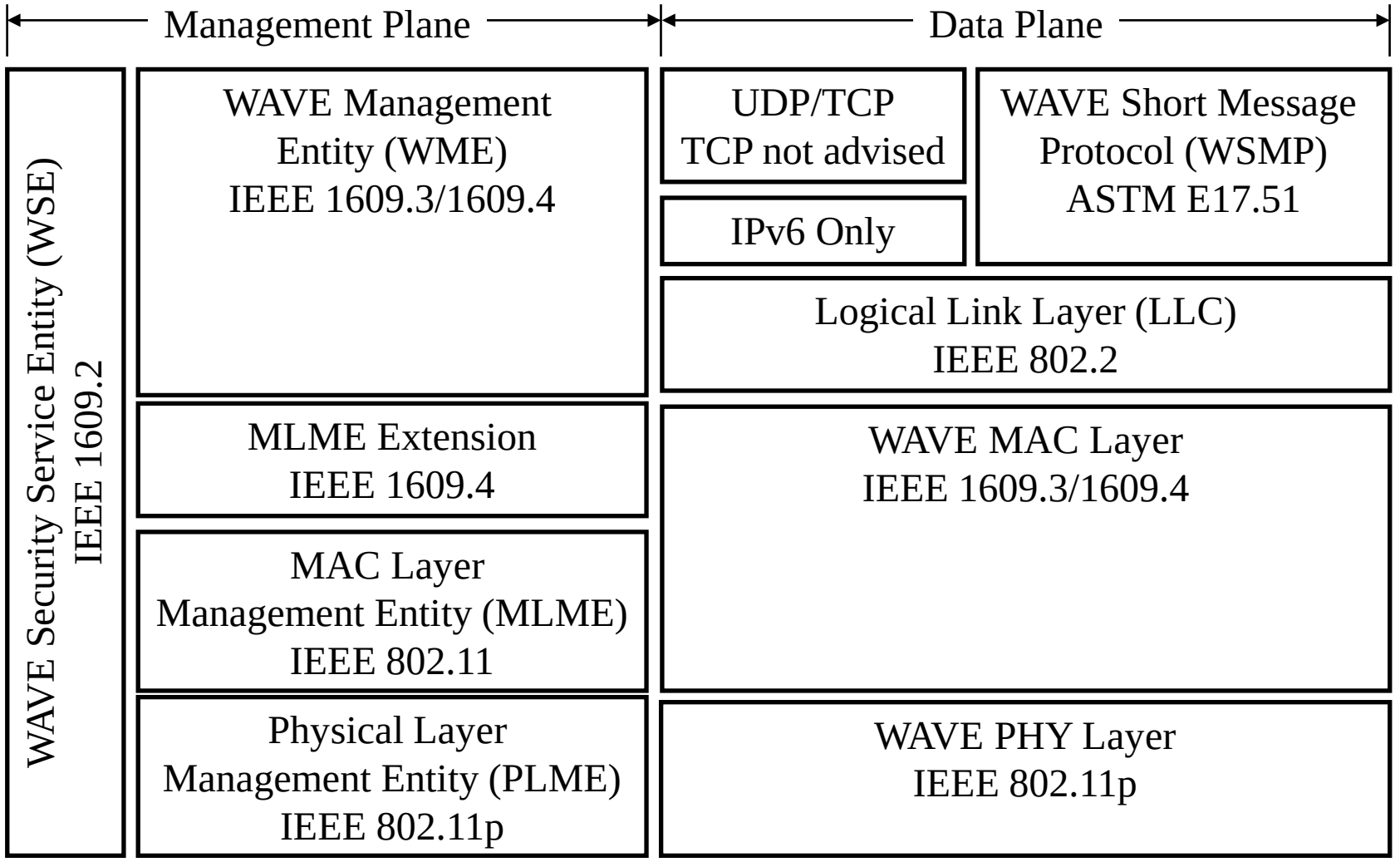
- ❑ How do WSMP nodes create a routing table to forward messages w/o a networking layer?

Point-to-point (one hop)

- ❑ You mention inline and offline in the video. Can you please explain what you were pointing to?

WSMP allows the node to indicate power level (inline0. When you use IPv6, there is no field in IP or MAC to indicate power level, etc. This is done offline via the management plane.

DSRC Protocol Components



Student Questions

- Why does the DSRC protocol stack favor IPv6 over IPv4, and how does this decision affect compatibility?

IPv4 is supposed to retire soon. However, it is not going away. Right now, the whole world is in dual mode.

- It says TCP is not advised, but is it officially supported by the specification? If so, will it remain supported, and what would the use case be?

Data transfer.

- How in-depth will we have to know this information for the exam?

As much as in the video.

DSRC Protocol Components (Cont)

- Wireless Access for Vehicular Environment (WAVE)
- **WAVE Short Message Service (WSMP):** ASTM E17.51
  Packets contain Priority, data rate, and power (how far should it go). Developed by American Society for Testing and Materials (ASTM) E17.
- **WAVE Management Entity (WME):** IEEE 1609.3 and IEEE 1609.4
  Registers Priority, data rate, and power for different applications
- **WAVE Security Entity (WSE):** IEEE 1609.2
  Data Encryption and Key management

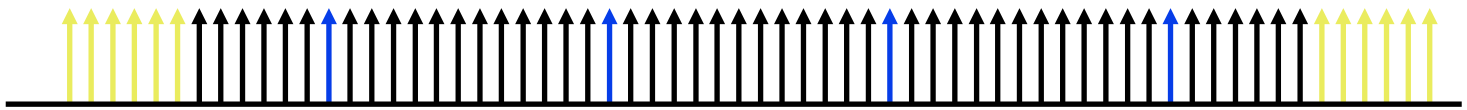
Student Questions

- What strategies can be used to ensure the availability of vehicles even when the network is down?

Vehicles are self-reliant. They will work without the extra features.

IEEE 802.11p PHY

- A Variation of IEEE 802.11a 5.8 GHz PHY
- OFDM with 64 subcarriers is used in 10 MHz
  - 48 data, 4 pilots, and 12 guard subcarriers as in 802.11a
  - Subcarrier spacing is half of that in 802.11a
  - All time parameters are doubled
  - Symbol size is twice of that in 802.11a
  - Guard Interval is also twice of that in 802.11a
    $\Rightarrow$ Allows larger multi-path delay spread
  - Data rate is half of that in 802.11a $\Rightarrow$ 27 Mbps max



Student Questions

- Why is subcarrier spacing less while symbol size and GI are larger? If signal interference is such a big issue, why would a larger subcarrier spacing not be used?

Better technology allows closer frequencies. Lower modulation rates (larger symbol times) ensure low error rates.

- What does it mean that all time parameters are doubled?

Bit time, symbol time, and inter-symbol gap are all doubles.

IEEE 802.11p PHY (Cont)

Parameter	IEEE 802.11a	IEEE 802.11p
Frequency Band	5.8 GHz	5.9 GHz
FFT Size	64	64
Data Subcarriers	48	48
Pilot Subcarriers	4	4
Channel Width	20 MHz	5, 10, 20 MHz
Symbol Duration	4 us	16, 8, 4 us
Guard Time	0.8 us	3.2, 1.6, 0.8 us
Subcarrier Spacing	312.5 kHz	78.125, 156.25, 312.5 kHz
Preamble	16 us	64, 32, 16 us

Student Questions

- On previous slide you mention time parameters are double of those in 802.11a but there are 3 values for the time intervals. Can you explain why this is?

The three values correspond to three channel widths. Longer symbol duration require longer guard time.

End of Q

DSRC Devices

- **Two Channels**: Control channel (CCH) for safety messages and network control. Service channel (SCH) for all other messages
- All devices use CCH and one or more SCH
- **Two types of devices**:
  - Multi-Channel: Can use CCH and SCH continuously
  - Single Channel: Single Radio for both CCH and SCH
    ⇒ Need time to switch between two channels
    ⇒ Guard time between switching
- All devices must monitor CCH for a common CCH Interval
  All devices should synchronize clocks to UTC.
  Generally, RSU's will have GPS clocks and transmit it in their beacons
- **WAVE Basic Service Set (WBSS):** Set of stations in one 802.11p network
- Neighboring WBSS use different Service Channels

Student Questions

- Does the device only have one CCH, or may it have multiple CCH?

One CCH

- How does a device ensure it is sync with UTC?

Via Internet. Just like your computer.

WAVE QoS

- **Two types of traffic**: IPv6 and WSM. No IPv4 because of address issues
- WSMP packets contain channel #, data rate, power level, and priority
- IPv6 streams need to inform MLME about their profile, including channel #, data rate, and power level
- IEEE 802.11e to support four queues for each channel
- **Channel Router**: Directs the packet to the right channel and queue
- **Channel Selector**: Monitors channels and schedules transmission with the specified power and data rate

Student Questions

- Which traffic is the IPv6 vs WSM traffic? You show slide 11 but don't indicate which is which.

IPv6 and WSMP are two L3 alternatives. Any application can use either alternative. Both can carry all traffic. These are designed by different organizations.

- Has there been any interest by auto manufacturers in implementing this technology?

Many cars now have satellite-based information systems.

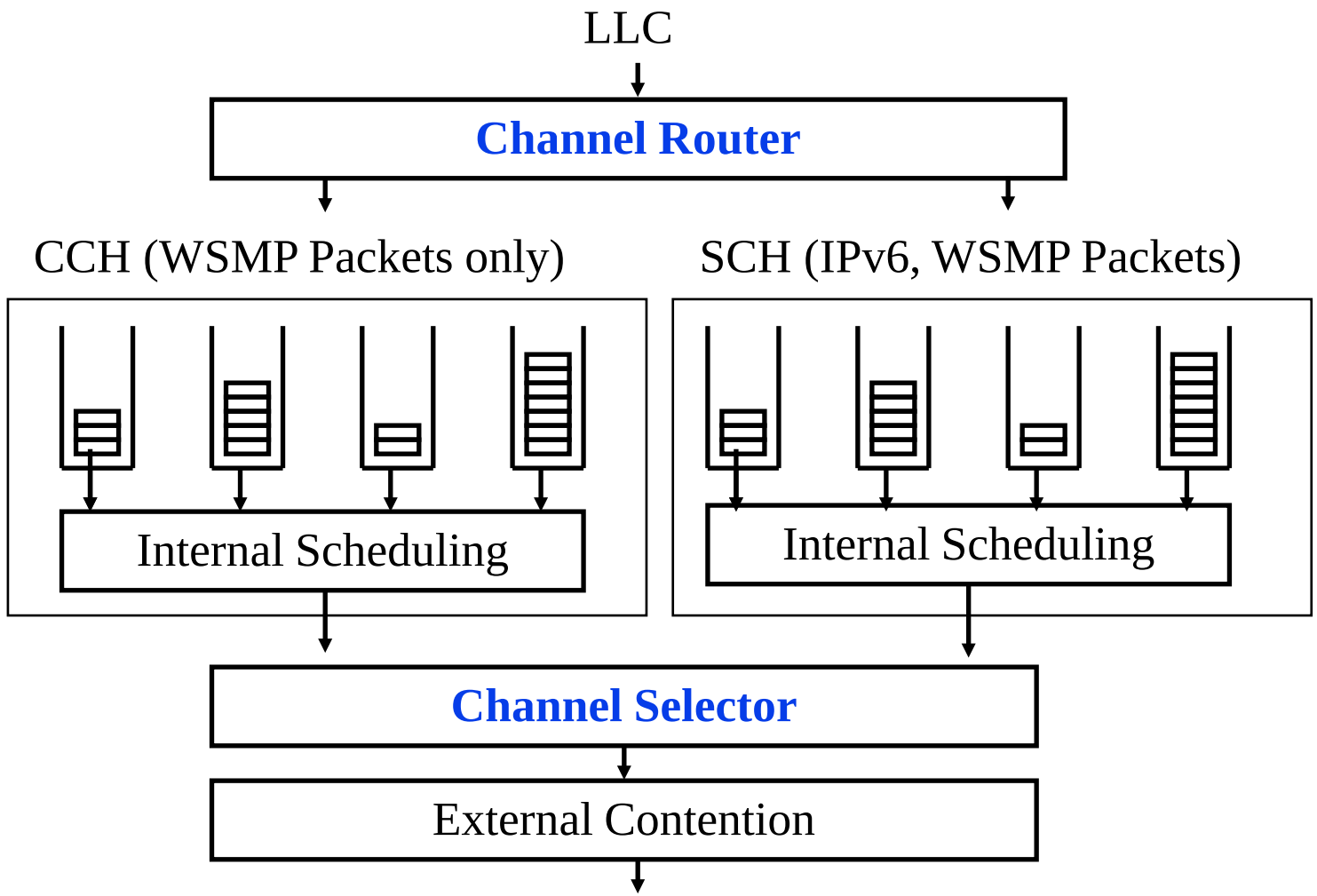
- Do the roadside units contain the hardware for the channel routers?

Yes. They would if ever implemented.

- Do incoming IPv6 streams inform the receiving MLME about profile, or do outgoing streams inform transmitting MLME?

Streams going from the tower to the mobile. Just as in your phone.

802.11p Channel Coordination Function



Student Questions

- An 802.11p device listens to all five channels at once? Is that why there is a channel selector?

No, the devices listen only to the control channel and then to the channel allocated to them for communication.

WBSS Formation

- Any WAVE device can start a WBSS when requested by an application.
- **Provider**: Device that starts WBSS (OBU or RSU). Generates announcements.
- **Users**: Devices that join WBSS
- **Persistent WBSS**: Announced every sync interval
- **Non-Persistent WBSS**: Short-lived. Announced at formation only, e.g., to support on-demand file download
- Server applications register with WME with a Provider Service Identifier (PSID) – like port numbers.
- A WBSS is initiated when the first application registers.
- The Provider Service Table (PST) is broadcast periodically

Student Questions

- Why does the PST need to be periodically broadcasted?

Similar to Beacons in Bluetooth, Wi-Fi, etc. You can either passively listen to what is available or broadcast a request to find out what services are available. Both are allowed.

- Why do we need WBSS since vehicles usually move quickly? The WBSS seems to be constantly changing.

This is equivalent to Basic Service Set in 802.11 like IBSS.

- Can you explain more about the Provider Service Table (PST)? Who will broadcast it periodically?

PST=List of services and their providers. WBSS base (provider) broadcasts it. It can be OBU or RSU.

WBSS Formation (Cont)

- User applications register their interests with their WME.
- WME monitors announcements and checks to see if the PST of a WBSS is of interest.
- WBSS are shutdown when there is no active application

Student Questions

Non-WBSS Communication

- **Outside the context of a BSS (OCB)** Mode:
  - Stations do not have to be a member of a BSS to transmit
  - A WAVE device can send a WSMP message to a broadcast address on CCH
  - Another WAVE device can respond to this WSMP message on the CCH
  - No BSS advertisement or synchronization
  - Timing Advertisements from provider: Default parameter values and a timestamp indicating local time
  - Authentication handled by higher layers
- OCB stations use slightly higher AIFS than WBSS members.
- OCB stations use wild cards in the BSS ID field in MAC frames

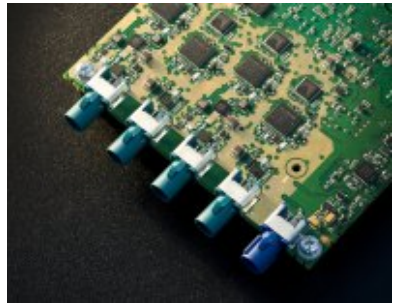
Student Questions

802.11p Products

- Arada Systems: OBU and RSU
- Cohda Wireless: WAVE-DSRC Radio
- NXP: Software Defined Radios for Cohda's radios
- Unex: OBUs
- Ittiam: HDL implementation (IP)
- Card Access Engineering: Product designs
- LITEPOINT: Test platform
- Rohde & Schwarz: Spectrum analyzers and signal generators

OBU

RSU



Radio

SDR+Radio

Student Questions

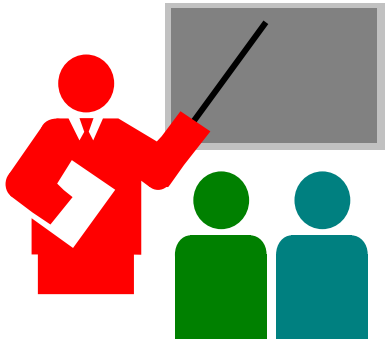
- I see one of the products references Hardware Description Languages. Where would FPGAs/Application Specific Computing be most beneficial for inter-vehicle communication?

FPGAs are generally used for low-volume applications.

Future

- DSRC is designed for short-range communication
- Good for the city, but long-range communication is also required on highways using cellular technology
- Will require multi-channel OBUs

Student Questions



Summary

1. VANETs have a dynamic topology and tight delay constraints for critical messages. V2V and V2I Communication between **RSU** and **OBU**.
2. DSRC uses **10MHz** Channels with OFDM in 5.9 GHz. CCH for Control and safety-critical messages. SCH for all other messages.
3. ASTM started WAVE with **WAVE Short Message Service Protocol**. IEEE 1609.1-4 standards extended 802.11 MAC management and security for DSRC.
4. IEEE 802.11p PHY **OFDM** is similar to 802.11a but with double symbols durations.
5. **QoS** similar to IEEE 802.11e but four queues for each channel.

Student Questions

- Are vehicular wireless networks commercial? Do vehicles have to pay to get the service, or is it open source like the map?

Only satellite-based and cellular-based networks are commercial.

Homework 8

- Your Name: _____

1. Broadcast within a limited area is called _____.
2. In _____ in VANETs, receivers integrated their own information and forward.
3. DSRC spectrum is in _____ GHz band.
4. DSRC spectrum is divided into _____ channels of _____ MHz each.
5. The middle channel is used as _____ channel while the two channels on each side are used as _____ channels.
6. WAVE PHY layer is _____
7. DSRC allows only IP version _____ traffic.
8. DSRC PHY uses _____ data carriers in a _____ MHz band.
9. WAVE uses _____ QoS queues for each channel.
10. Any WAVE device can start a _____ and become a provider.
11. A _____ WBSS is announced every sync interval.

Student Questions

- When are we supposed to turn in HW8?
- Will the homework be due Wednesday due to fall break?

Yes. All homework due on the 10th is due on the 12th. Project selection is due on the 11th, giving us one day to allocate the projects.

- Can you please solve HW 8?

Sure, at the end of this class.

- The published slides contains a quiz 8-37.

That homework is no longer used, so removed. Similar quizzes are now in the video.

Reading List

- Christoph Sommer, Falko Dressler, "Vehicular Networking," Cambridge University Press, November 2014, 384 pp., ISBN:978-1-107-04671-9 (Safari Book).
- Karagiannis, G.; Altintas, O.; Ekici, E.; Heijenk, G.; Jarupan, B.; Lin, K.; Weil, T., "Vehicular Networking: A Survey and Tutorial on Requirements, Architectures, Challenges, Standards and Solutions," in *Communications Surveys & Tutorials*, *IEEE* , vol.13, no.4, pp.584-616, Fourth Quarter 2011, http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5948952 (Must Read)

Student Questions

Wikipedia Links

- http://en.wikipedia.org/wiki/IEEE_802.11p
- http://en.wikipedia.org/wiki/Wireless_Access_for_the_Vehicular_Environment
- http://en.wikipedia.org/wiki/Dedicated_short-range_communications
- http://en.wikipedia.org/wiki/Vehicular_ad_hoc_network
- http://en.wikipedia.org/wiki/Intelligent_vehicular_ad-hoc_network
- http://en.wikipedia.org/wiki/Vehicular_communication_systems
- http://en.wikipedia.org/wiki/Abiding_Geocast_/_Stored_Geocast
- http://en.wikipedia.org/wiki/Geocast
- http://en.wikipedia.org/wiki/Vehicle_infrastructure_integration

Student Questions

References

- Y. L. Morgan, “Notes on DSRC & WAVE Standards Suite: Its Architecture, Design and Characteristics,” IEEE Communications Surveys and Tutorials, Vol 12, No. 4, 2010, pp. 504-518, http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5462975
- R. Aquino-Santos, A. Edwards, and V. Rangel-Licea, "Wireless Technologies in Vehicular Ad-Hoc Networks," IGI Global, Feb 2012, 382 pp., ISBN:1466602090.
- Hadded, M.; Muhlethaler, P.; Laouiti, A.; Zagrouba, R.; Saidane, L.A., "TDMA-Based MAC Protocols for Vehicular Ad Hoc Networks: A Survey, Qualitative Analysis, and Open Research Issues," in Communications Surveys & Tutorials, IEEE , vol.17, no.4, pp.2461-2492, Fourth quarter 2015, http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7117340&isnumber=7331734
- Suthaputchakun, C.; Zhili Sun, "Routing protocol in intervehicle communication systems: a survey," in Communications Magazine, IEEE , vol.49, no.12, pp.150-156, December 2011, http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6094020

Student Questions

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- Cailean, A.-M.; Cagneau, B.; Chassagne, L.; Popa, V.; Dimian, M., "A survey on the usage of DSRC and VLC in communication-based vehicle safety applications," in Communications and Vehicular Technology in the Benelux (SCVT), 2014 IEEE 21st Symposium on , vol., no., pp.69-74, 10-10 Nov. 2014, http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7046710
- Araniti, G.; Campolo, C.; Condoluci, M.; Iera, A.; Molinaro, A., "LTE for vehicular networking: a survey," in Communications Magazine, IEEE , vol.51, no.5, pp.148-157, May 2013, http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6515060
- ASTM, "ASTM E2213 - 03(2010) Standard Specification for Telecommunications and Information Exchange Between Roadside and Vehicle Systems — 5 GHz Band Dedicated Short Range Communications (DSRC) Medium Access Control (MAC) and Physical Layer (PHY) Specifications," http://www.astm.org/Standards/E2213.htm Available for purchase.

Student Questions

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- IEEE, "IEEE standard 802.11p: Wireless LAN medium access control (MAC) and physical layer (PHY) specifications: Amendment 6- Wireless access in vehicular environments," 2010, http://standards.ieee.org/getieee802/download/802.11p-2010.pdf
- IEEE P1609.1 SWG, "IEEE 1609.1 Trial-Use Standard for Wireless Access in Vehicular Environment (WAVE) Resource Manager," 2009
- IEEE P1609.2 SWG, "IEEE 1609.2 Trial Use Standard for Wireless Access in Vehicular Environments – Security services for Applications and Management Messages," June 2009
- IEEE P1609.3 SWG, "IEEE 1609.3-2010: IEEE standard for wireless access in vehicular environments (WAVE) – Networking services," 2010.
- IEEE P1609.4 SWG, "IEEE 1609.4-2010: IEEE standard for wireless access in vehicular environments (WAVE) – Multi-channel operation," 2010.

Student Questions

Acronyms

AIFS	Arbitrated Inter-Frame Spacing
ASTM	American Society for Testing and Materials
BPSK	Binary Phase Shift Keying
BSS	Basic Service Set
CCH	Control Channel
dBm	Decibel mill watt
DSRC	Dedicated short-range communications
EIRP	Equivalent Isotropically Radiated Power
FCC	Federal Communications Commission
FFT	Fast Fourier Transform
GHz	Giga Hertz
GPS	Global Positioning System
HALL	High Availability Low Latency
HDL	Hardware Description Language
ID	Identifier
IEEE	Institution for Electrical and Electronic Engineers

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Acronyms (Cont)

IPv4	Internet Protocol version 4
IPv6	Internet Protocol version 6
LAN	Local Area Network
LLC	Logical Link Control
MAC	Media Access Control
MHz	Mega Hertz
MLME	MAC Layer Management Entity
OBU	On-board Unit
OCB	Outside the context of a BSS
OFDM	Orthogonal Frequency Division Multiplexing
PHY	Physical Layer
PLCP	Physical Layer Convergence Protocol
PLME	Physical Layer Management Entity
PSID	Provider Service Identifier
PST	Provider Service Table
QoS	Quality of Service

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Acronyms (Cont)

- RSU Roadside Unit
- SCH Service Channel
- SDR Software Defined Radio
- SWG Standards Working Group
- TCP Transmission Control Protocol
- UDP User Datagram Protocol
- UTC Coordinated Universal Time
- VANET Vehicular Ad-Hoc Networks
- WAVE Wireless Access for Vehicular Environment
- WBSS WAVE Basic Service Set
- WME WAVE Management Entity
- WSM WAVE Security Management Entity
- WSMP WAVE Short Message Protocol

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Related Modules

CSE567M: Computer Systems Analysis (Spring 2013),
https://www.youtube.com/playlist?list=PLjGG94etKypJEKjNAa1n_1X0bWWNyZcof

CSE473S: Introduction to Computer Networks (Fall 2011),
https://www.youtube.com/playlist?list=PLjGG94etKypJWOSPMh8Azcgy5e_10TiDw

Recent Advances in Networking (Spring 2013),
https://www.youtube.com/playlist?list=PLjGG94etKypLHyBN8mOgwJLHD2FFIMGq5

CSE571S: Network Security (Fall 2011),
https://www.youtube.com/playlist?list=PLjGG94etKypKvzfVtutHcPFJXumyyg93u

Video Podcasts of Prof. Raj Jain's Lectures,
https://www.youtube.com/channel/UCN4-5wzNP9-ruOzQMs-8NUw

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