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The Future of V2X: 30 MHz Application Map

Tim Drake, ITS America Mark Knellinger, Cisco Systems, Inc. Jim Misener, Qualcomm Technologies, Inc. John Kenney, Toyota Motor North America



Opening Remarks

Shailen Bhatt, President and CEO, ITS America



Overview of Webinar

- Presentations
 - Tim Drake, ITS America
 - Mark Knellinger, Cisco Systems, Inc.
 - Jim Misener, Qualcomm Technologies, Inc.
 - John Kenney, Toyota Motor North America
- Questions



Overview of FCC Action

- FCC Proposal on 5.9 GHz Band
 - Reallocates the lower 45 MHz of spectrum for use by unlicensed devices
 - Leaves only 30 MHz for V2X technologies
 - Requires V2X technologies to use C-V2X
 - Approved in November 2020
 - Still waiting for the Final R&O to be published
- FNPRM
 - Includes issues related to transition timeline, reimbursement, power limits for outdoor unlicensed devices

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ITS America's Response

- ITS America strongly opposes the reallocation of the lower 45 MHz, and continues to advocate that the full 75 MHz is needed for transportation communications
- Main problems with the proposal:
 - Does not leave enough spectrum for current and anticipated V2X applications
 - Does not adequately protect V2X spectrum from out-of-band interference



Future of V2X Working Group

- ITS America convened a Future of V2X Working Group to evaluate the expected impacts of the FCC proposal
 - Comprised of infrastructure owner operators, automotive manufacturers, and technology companies
- One priority task was to identify which message types and applications would likely be deployed in a 30 MHz spectrum environment and which would be lost:
 - Demonstrates the proposal's negative impact on transportation safety
 - Identifies a path forward to safely deploy V2X technologies should the FCC proposal be finalized

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Application Map

- Evaluated numerous V2X applications based on spectrum requirements, stakeholder priority, and likely safety benefit
- Spectrum requirements were calculated based on assumptions about:
 - The number of vehicles within communication range
 - Packet size
 - Repetition rate
 - Activity factors
 - Spectral efficiency
 - Channel utilization



- Stakeholder priority was assessed through informal discussion and a limited survey of IOO priorities for applications
- Likely safety benefit was assessed through informal discussion and the NHTSA Vehicle Safety Communications Project Final Report



- Developed a preliminary application map attempting to show which message types and applications are likely to be deployed in a limited 30 MHz environment, and which are likely not to be deployed
- The application map is not final nor conclusive, it is intended as a starting point for discussions within the transportation industry

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- Message Types Likely to Be Deployed
 - Basic Safety Message (BSM)
 - Intersection Mapping (MAP)
 - Signal Phase and Timing (SPaT)
 - Road Safety Message (RSM)
 - Signal Request Message (SRM)
 - Signal Status Message (SSM)
 - GNSS Correction Messages (RTCM)
 - Probe Vehicle Data (PVD)



- Message Types Likely to Be Lost
 - Collective Perception Messages (CPM)
 - Maneuver Coordination Messages (MCM)
 - Personal Safety Messages (PSM)



Caveats and Limitations

- Message types and applications based on:
 - Existing applications with developed standards and anticipated applications with standards in development
 - Existing and anticipated methods of deployment
- Applications could move between lists based on:
 - Message type used and method of deployment
 - Changes to application standards
 - Results from actual deployment



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V2X Application	IOO Priority	Safety Priority	Message Used
Message Types and Applications Likely in a	a 30 MHz S	cenario	
Forward Collision Warning	5.00	5	BSM
Pre-Crash Sensing	4.67	5	BSM
Cooperative Collision Warning	4.33	5	BSM
Cooperative Forward Collision Warning	4.33	5	BSM
Approaching Emergency Vehicle Warning	4.33	5	SRM, SSM, RSA
Emergency Vehicle Signal Preemption	4.33	5	SRM, SSM, RSA
Emergency Electronic Brake Lights	4.33	4	BSM
Work Zone Traveler Information	4.33	4	TIM
Emergency Vehicle Preemption	4.00	4	SRM, SSM, RSA
Blind Spot/Lane Change Warning	4.00	4	BSM
Curve Speed Warning	3.67	4	TIM
Motorist Advisories and Warnings	3.67	4	TIM
Ramp Speed Warning	3.67	4	TIM
Signal Priority (transit, freight)	3.67	3	SRM, SSM, RSA
Freight-Specific Dynamic Travel Planning and Performance	3.67	2	TIM
n-Vehicle Signage Warning	3.33	4	TIM
SOS Services	3.33	4	TIM
ntelligent Traffic Signal System	3.33	3	SPAT, MAP, SSM
CV-Enabled Turning Movement and Intersection Analysis	3.33	2	BSM
n-Vehicle Amber Alert Warning	3.33	2	TIM
ncident Scene Work Zone Alerts for Drivers and Workers	3.33	2	TIM
Road Condition Warning	3.00	3	TIM
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30 MHz So 3.00 3.00 3.00 3.00 3.00 2.67 2.67 2.67 2.67	2 2 2 2 2 2 2 3 3 3 3	BSM BSM, SPAT, MAP PVD SPAT, MAP TIM BSM BSM, TIM
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3.00 3.00 2.67 2.67 2.67 2.67	2 2 3 3 3	PVD SPAT, MAP TIM BSM BSM, TIM
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2.67	2	BSM
2.67	2	TIM
2.67	2	TIM
2.67	2	TIM
2.33	2	BSM
2.33	2	TIM
2.33	1	TIM
2.33	1	BSM
2.00	2	BSM
2.00	1	BSM
2.00	1	TIM
1.67	1	TIM
1.67	1	TIM
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V2X Application	IOO Priority	Safety Priority	Message Used
Message Types and Applications Unlikely in	n a 30 MHz	z Scenario	
Intersection Collision Warning	5.00	5	ICA, CPM
Highway/Railroad Collision Warning	4.67	5	ICA, CPM
Work Zone Warning	4.67	4	RSA, TIM, PSM
Wrong Way Driver Warning	4.33	5	RSA, TIM
Emergency Electronic Brake Lights	4.33	5	ICA, CPM
Mobile Accessible Pedestrian Signal System	4.33	5	ICA, CPM
Pedestrian in Signalized Crosswalk Warning (transit)	4.33	5	PSM, ICA, CPM
Pedestrian Crossing Information	4.33	5	PSM, TIM
Road Condition Warning	4.33	4	RSA
Queue Warning	4.33	3	RSA
Traffic Signal Violation Warning	4.33	3	RSA, ICA, CPM
Blind Merge Warning	4.00	5	ICA, CPM
Left Turn Assist	4.00	4	ICA, CPM
Stop Sign Violation Warning	4.00	3	RSA, ICA, CPM
Cooperative Adaptive Cruise Control	4.00	2	ICA, CPM
Cooperative Vehicle-Highway Automation System (Platoon)	4.00	2	ICA, CPM
Intersection Movement Assist	3.67	4	ICA, CPM
Advanced Traveler Information System	3.67	4	PVD



V2X Application	IOO Priority	Safety Priority	Message Used				
Message Types and Applications Unlikely in a 30 MHz Scenario							
Reduced Speed/Work Zone Warning	3.67	3	TIM, RSA				
Left Turn Assistant	3.67	3	ICA, CPM				
Blind Spot Warning	3.67	3	ICA, CPM				
Vehicle Turning Right in Front of Bus (transit)	3.00	3	ICA, TIM, SRM,				
			SSM				
Highway Merge Assistant	3.00	3	ICA, CPM				
Lane Change Warning	3.00	3	ICA, CPM				
Dynamic Speed Harmonization	3.00	2	ICA, CPM				
Incident Scene Pre-Arrival Staging Guidance for Emergency	3.00	2	ICA, CPM, TIM				
Responders							
Probe-based Pavement Maintenance	3.00	1	TIM, RSA				
Vehicle-to-Vehicle Road Feature Notification and Perception	2.67	4	RSA				
Sharing							
Low Bridge Warning	2.67	3	TIM, RSA				
Stop Sign Movement Assist	2.67	3	ICA, CPM				
Visibility Enhancer	2.67	2	ICA, CPM				
Connection Protection	2.67	2	1609				
Eco-Traffic Signal Priority	2.67	2	SRM, SSM, RSA				
Low Parking Structure Warning	2.00	3	RSA				
Dynamic Transit Operations	2.00	1	SRM, SSM, RSA				
Dynamic Ridesharing	1.67	1	RSA				

Remaining Concern: Interference

- This Application Map is based on a 30 MHz spectrum environment unencumbered by interference from out-of-band emissions
- Expected interference from unlicensed devices operating in the lower 45 MHz or the 6 GHz band must be mitigated
- Power limits for outdoor unlicensed devices are a subject of the FNPRM



Next Steps and Additional Questions

Next Steps

- Run simulations and evaluate the assumptions used in creating the preliminary application map
- Refine the prioritization of applications based on IOO priority and expected safety benefit
- Incorporate additional feedback from transportation stakeholders

Additional Questions

- How should Channel 180 be best used to provide V2X functionality?
- How should other critical service needs, such as certificate top-off, certificate revocation lists, misbehavior detection and reporting, and device management be provided?

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Mark Knellinger, Cisco Systems, Inc.







- Applications across technologies DSRC and CV2X
- Compiled from current message types
- Pulled from existing deployments
- Leverage sources NHTSA, ARC-IT Service packages and others

Spectrum Usage Calculations

• Independent of technologies – DSRC and CV2X, SAE Message Set

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- Basic formula for calculating application bandwidth
 - B=(M*N*F*a)/(e*u)
 - M = number of vehicles within the communication range
 - N = packet size (bits, not bytes)
 - F = repetition rate (Hz)
 - a = activity factor or fraction of vehicles which transmit repetitive messages
 - e = spectral efficiency
 - u = channel utilization
- Pulled from existing deployments
- Evaluated Message Type Mix and Vehicle Densities

Example Sheet

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B=(M*N*F*a)/(e*u)											
M = number of vehicles within the c	ommunication range										
N = packet size (bits, not bytes)											
F = repetition rate (Hz)											
a = activity factor or fraction of vehi	cles which transmit r	epetitive n	nessages. I	n the 5GAA	report, a =	1 since wer	e assume a	n end stat	e of 100% mar	ket penetration	ı.
e = spectral efficiency											
u = channel utilization											
DSRC in High Densities	1/2 mile radius from	Radio/RSU	; 8 lanes, 3	0 foot spaci	ng, 10 inte	rsections in	radius				
	BSM	PSM	SPAT	MAP	ICA	TIM	SRM	SSM	PVD	CPM	
Vehicles/RSU in Range	1408.00	20.00	10.00	10.00	0.00	20.00	3.00	0.00	1408.00	0.00	
Packet Size in bits	2480.00	1488.00	1680.00	8880.00	208.00	1552.00	1232.00	0.00	1632.00	0.00	
Repetition Rate	4.00	6.00	3.33	1.00	10.00	10.00	10.00	10.00	1.00	10.00	
Activity Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
Spectral Efficiency	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	
Channel Utilization	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	
Megahertz	55.87	0.71	0.22	0.36	0.00	1.24	0.15	0.00	9.19	0.00	67.74 Mhz
DSRC in Medium Densities	1/2 mile radius from	Radio/RSU	; 4 lanes, 3	0 foot spaci	ng, 10 inte	rsections in	radius				
	BSM	PSM	SPAT	MAP	ICA	TIM	SRM	SSM	PVD	CPM	
Vehicles/RSU in Range	704.00	20.00	20.00	20.00	0.00	40.00	6.00	0.00	704.00	0.00	
Packet Size in bits	2480.00	1488.00	1680.00	8880.00	208.00	1552.00	1232.00	0.00	1632.00	0.00	
Repetition Rate	5.00	6.00	3.33	1.00	10.00	10.00	10.00	10.00	1.00	10.00	
Activity Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
Spectral Efficiency	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	
Channel Utilization	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	
Megahertz	34.92	0.71	0.45	0.71	0.00	2.48	0.30	0.00	4.60	0.00	44.17 Mhz

Application Priorities Included

- Safety Priority
- Roadway operator inputs on application priority

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Vehicle OEM potential usage



Caveats

- Many new message types are being created to improve existing applications and address emerging applications
- Technology improvements currently in development, ie. CV2X prioritizations will address some application viability
- Major areas around over the air updates and certificate management were not addressed in the spectrum usage

Jim Misener, Qualcomm Technologies, Inc.



Today: Fitting Applications into One Channel

Tomorrow: Addressing Advanced Applications

Jim Misener Sr. Director, Product Management Global V2X Ecosystem Lead Qualcomm Technologies, Inc. Qualcom

5G V2X builds on C-V2X

with advanced use cases



Traffic Families

Defined in SAE J3161 WIP C-V2X Deployment Profiles



Communication profiles (# subchannels, data rate, retransmission) set for V2V, V2I and I2V

Allows V2V and V2I services to be delivered by one 20 MHz Radio* * Opportunity for lower 10 MHz can be used for platooning or other apps

Priority of Different Traffic Families

Traffic Type		Safety	Services		Mobility Services			
Traffic Direction	V2V I2V				V2I - I2V			
Traffic Families	Critical V2V	Essential V2V	Critical I2V	ical Essential V I2V Transac		Low Priority	Background	
Minimum Priority (PPPP)	2	5	3	5	6	7	8	
Minimum packet delay budget	20 ms	100 ms	100 ms	100 ms	100 ms	100 ms	100 ms	
Example Messages	Critical BSM, EVA	BSM	RSM, MAP	SPaT	EFC/Toll	ТІМ	TCP, UDP	



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John Kenney, Toyota Motor North America



Ch. 183 is the new Ch. 172



• SAE J2945 includes industry consensus on use of DSRC Ch. 172



BSM = Basic Safety Msg; SPAT = Signal Phase and Timing; RSM = Road Safety Msg; CSW = Curve Speed Warning; RSZW = Reduced Speed Zone Warning; WSA = WAVE Service Advertisement

Ch. 183 is the new Ch. 172



20 MHz LTE V2X ~ 10 MHz DSRC



BSM = Basic Safety Msg; SPAT = Signal Phase and Timing; RSM = Road Safety Msg; CSW = Curve Speed Warning; RSZW = Reduced Speed Zone Warning; WSA = WAVE Service Advertisement

Packing the suitcase: What Fits?





If it fits it ships?



Messages are like Eggs: Fragile





If it fits it ships?





Messages like eggs: Fragile

Messages are like Eggs: Fragile





Messages like eggs: Fragile

Resist temptation to over pack

Not all applications are created equal





Find a balance: one large, several small





30 MHz: Industry Consensus Needed



Regulations won't limit applications in 30 MHz

- FCC likely will not
- USDOT likely cannot





30 MHz Application Map:

- 1st step to develop industry consensus
- Will not stop rogue deployment
- Discipline needed to ensure performance for core applications

3GPP Priority: A blunt instrument

- PPPP: ProSe Per Packet Priority
- Limits air time per priority class <u>per device</u>
 - For example, as a function of channel busy ratio
- When # devices varies up to hundreds, hard to find effective limits



 Conclusion: be conservative about allowing low priority applications on Ch. 183



Questions

