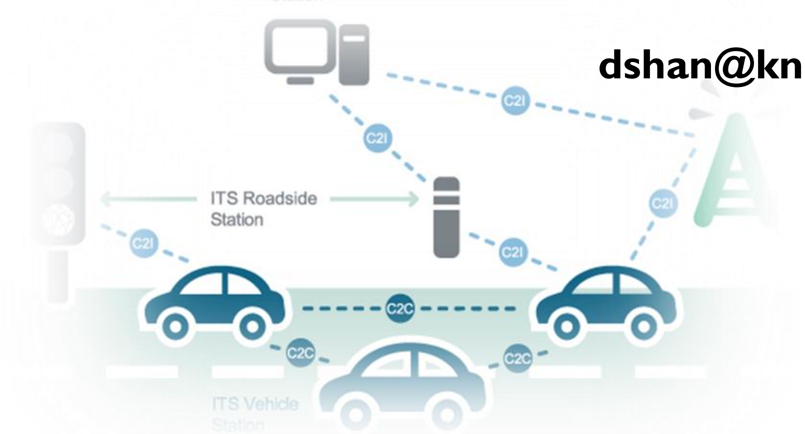
KNU KYUNGPOOK NATIONAL UNIVERSITY

V2X 통신 응용 기술과 발전 방향

2014.06.24.

경북대학교 IT•자동차융합연구센터
한동석
dshan@knu.ac.kr



Contents

I. 차량 통신 시스템 개요

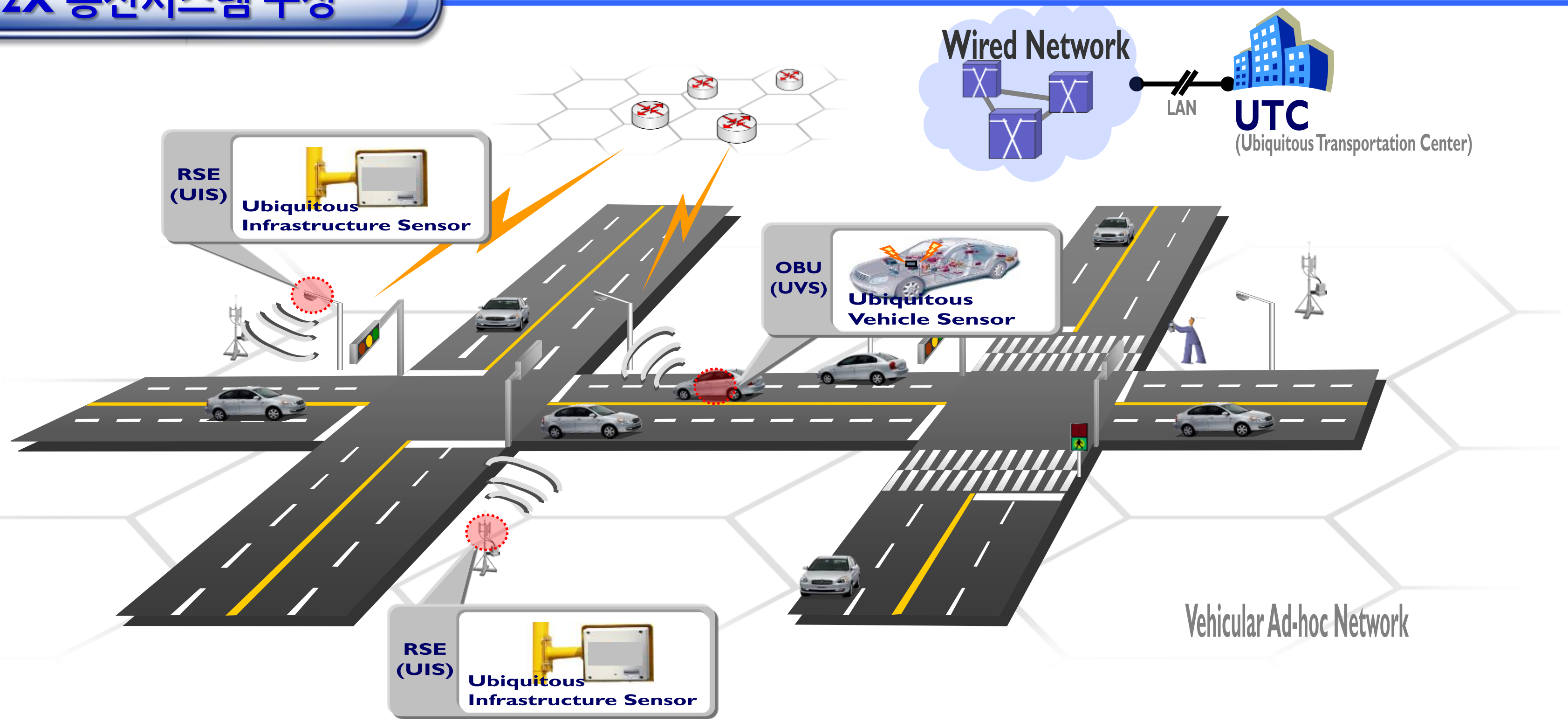
V2X 통신

- Ubiquitous Transportation Sensor Network
- Real-time traffic and vehicle information providing system based on Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I) and I2I communications

V2X 특징

- Seamless communication for V2V, V2I, and I2I
- Real-time vehicle information gathering
- Providing localized information on traffic condition and neighbor vehicles
- Establishment of VANET in fast moving condition

V2X 통신시스템 구성



I. 차량 통신 시스템 개요

CITAC Center for IT & Automobile Convergence

V2X 통신시스템 주요 특징

- **Periodic information sending from OBU to UTC**
  - Period : 100 ms
  - Vehicle information sending in infrastructure free area (V2V2I2C, message piggybacking)
- **Rapid transmission of emergency message**
  - In 50 ms
  - V2V multihop transmission, UIS cooperated transmission (V2I2V,V2I2I2V)
- **Embedded u-TSN security module**
  - V2V Authentication,V2C Authentication, Data encryption

V2X 통신 성능

- **IEEE 802.11p system**
  - Data rate : 3, 4.5 Mbps (BPSK), 6, 9 Mbps (QPSK), 12, 18 Mbps (16QAM), 24, 27 Mbps (64QAM)
  - Bandwidth : 10 MHz
  - Channel Switching : Interval 100 ms (CCH/SCH 50 ms, guard time 10 ms)
  - Throughput : 1.0Mbps (IEEE 802.11p, data rate 3 Mbps)
  - Coverage : 500 m ~ 1000 m (V2V,V2I), 1000m (I2I, IEEE 802.11g)
  - Vehicle Velocity : 160 km/h

2. WAVE 표준

CITAC
Center for IT & Automobile Convergence

DSRC

- 교통정보제공 과금체계용 DSRC 사용
- 변화하는 ITS 환경의 요구 발생

↓

- 차세대 통신 기술 필요

Wi-Fi 진화

- IEEE 802.11a (Wi-Fi) 기반

↓

- IEEE 802.11p (WAVE) 표준지정

→ 도로 및 차량 내 전파환경을 반영

IEEE 1609 추가

- 서비스 관련규격 재정작업 중

- 자원관리, 보안, 네트워크, 멀티채널 동작 등

WAVE 탄생

- IEEE 802.11p + IEEE 1609

↓

- IEEE 802.11p/WAVE

→ WAVE 규격 탄생

2. WAVE 표준

CITAC
Center for IT & Automobile Convergence

DSRC : Dedicated Short Range Communication

- 주파수 대역할당 및 노변 기지국과 차량 단말기 간의 서비스 정보를 주고 받기 위한 양방향 통신 방식을 제안
- **Short range radio**
  - 300m (1000m max)
- **High data rate**
  - 6-27 Mbps
- **Half-duplex**
  - Station can only send or transmit, but not both at the same time

Old DSRC

- 915 MHz
- Range < 30 meter
- Data rate = 0.5 Mbps
- Designed for ETC, but can be used for other application
- Single unlicensed channel
- Requires special (custom) chip set & software
- Vehicle to roadside communication
- Command-response

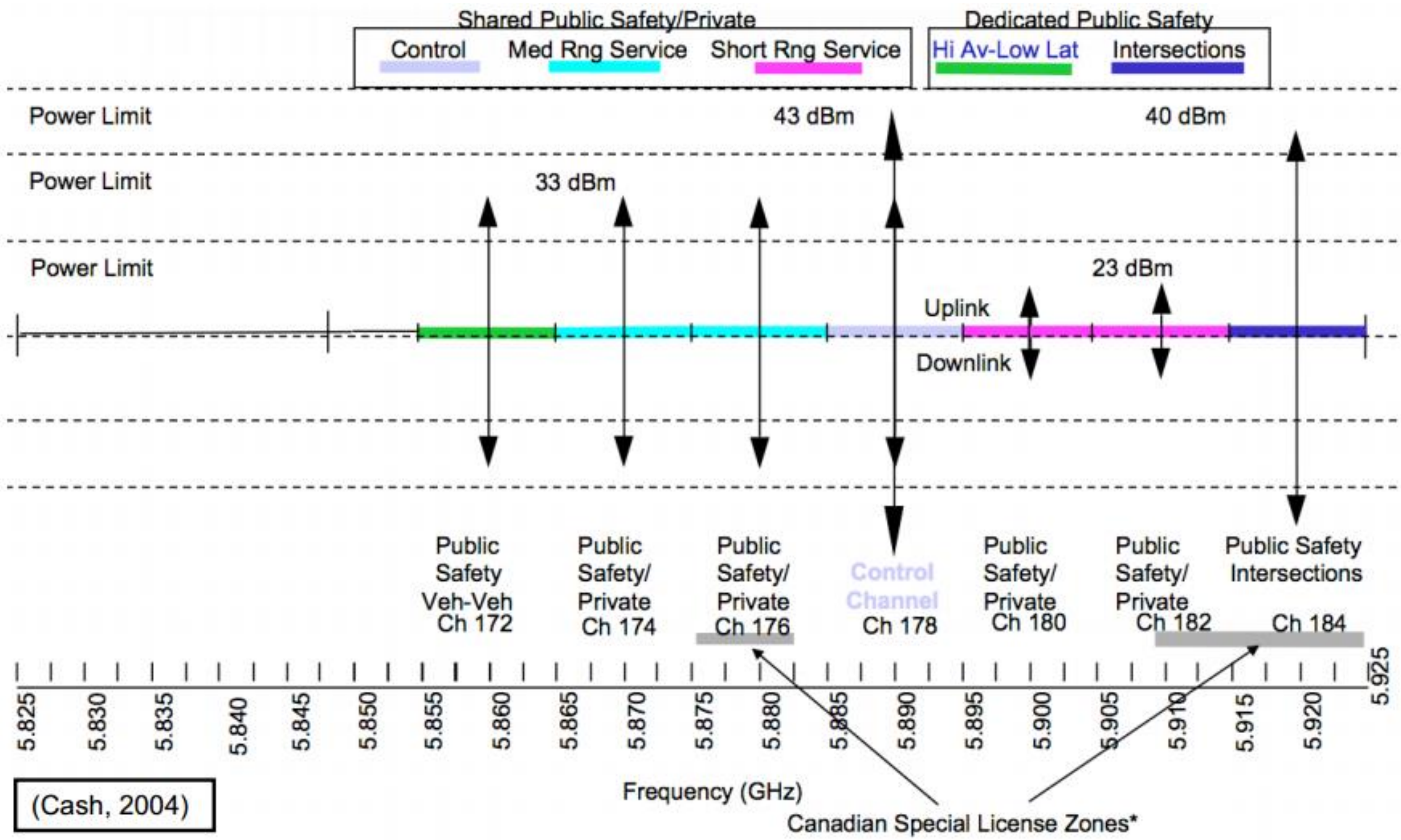
- ETC (Electronic Toll Collection) : 전자 요금 징수

New DSRC

- 5.9 GHz
- Range to 1000 meter
- Data rate 6 to 27 Mbps
- Designed for general internet access, can be used for ETC
- 7 licensed channels
- Uses open off-the-shelf chip set & software
- Vehicle to roadside & Vehicle to vehicle communication
- Command-response & peer to peer

2. WAVE 표준

- DSRC – Channel Allocation



CITAC
Center for IT & Automobile Convergence

- DSRC – How does it works?

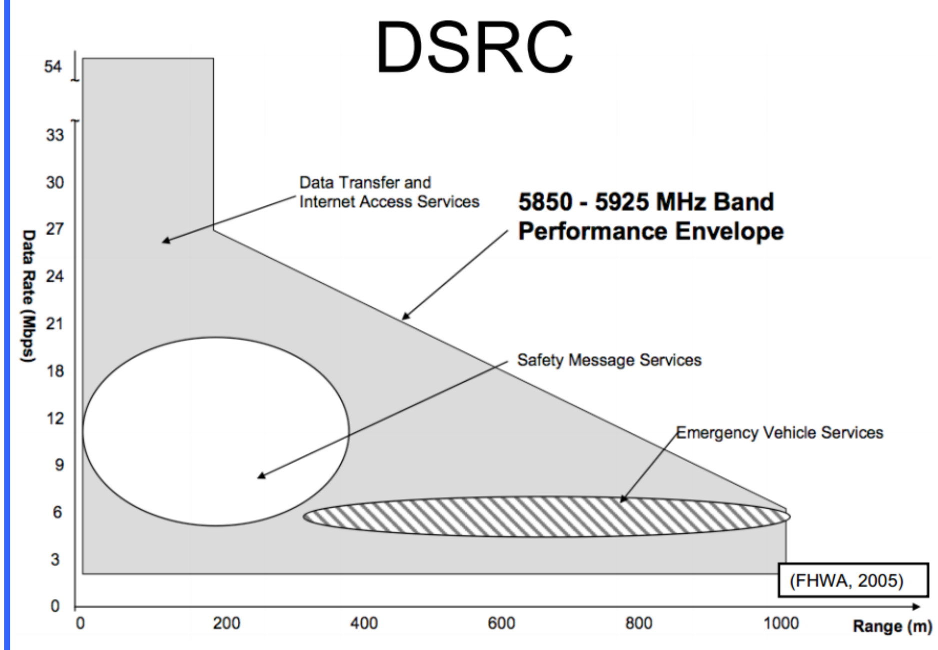
RSU

- Announces to OBUs 10 times per second the applications it supports, on which channels

OBU

- Listens on channel 172
- Authenticates RSU digital signature
- Executes safety apps first
- Then, switches channels
- Executes non-safety apps
- Returns to channel 172 and listens

DSRC performance



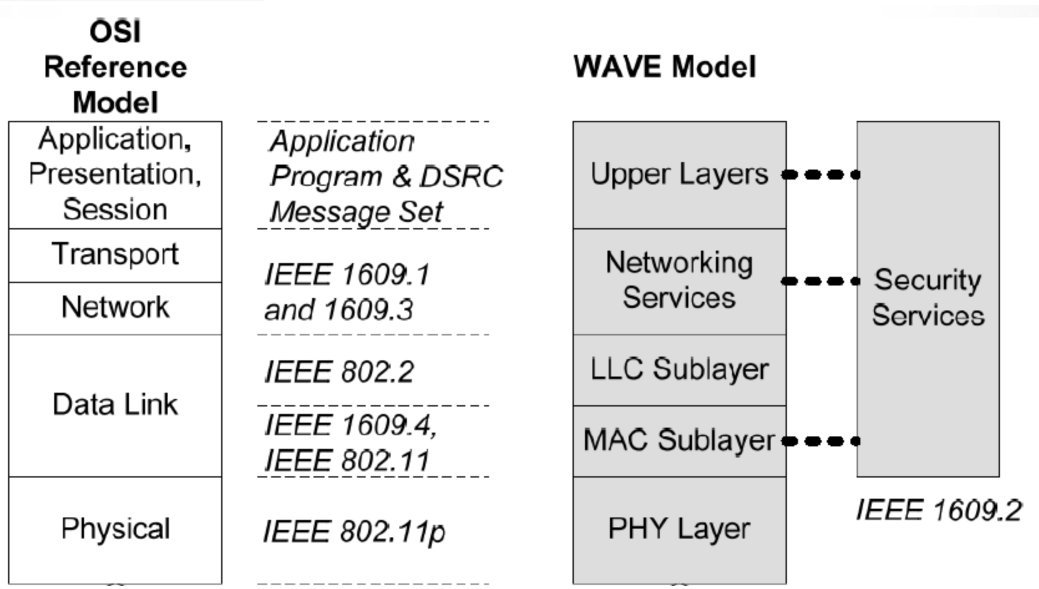
2. WAVE 표준

CITAC
Center for IT & Automobile Convergence

WAVE : Wireless Access in Vehicular Environment

- 고속으로 주행하는 차량 환경에서 통신서비스를 제공하기 위하여 특화된 차세대 ITS 통신 기술
- WLAN 기술을 기반으로 자동차 환경에 맞도록 수정
- DSRC (Dedicated Short Range Communication) 기술의 일종
- V2I (Vehicle-to-Infrastructure)과V2V(Vehicle-to-Vehicle) 통신을 지원

OSI vs WAVE

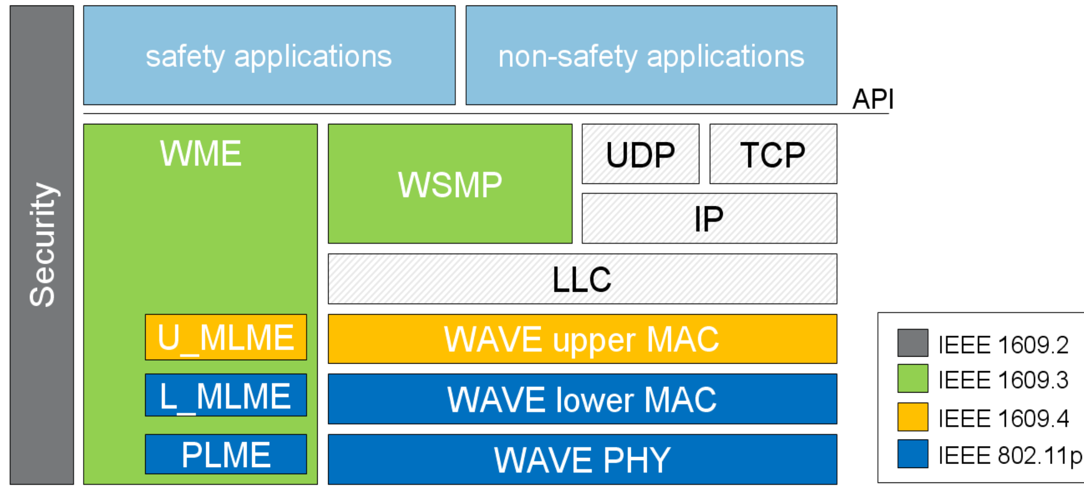


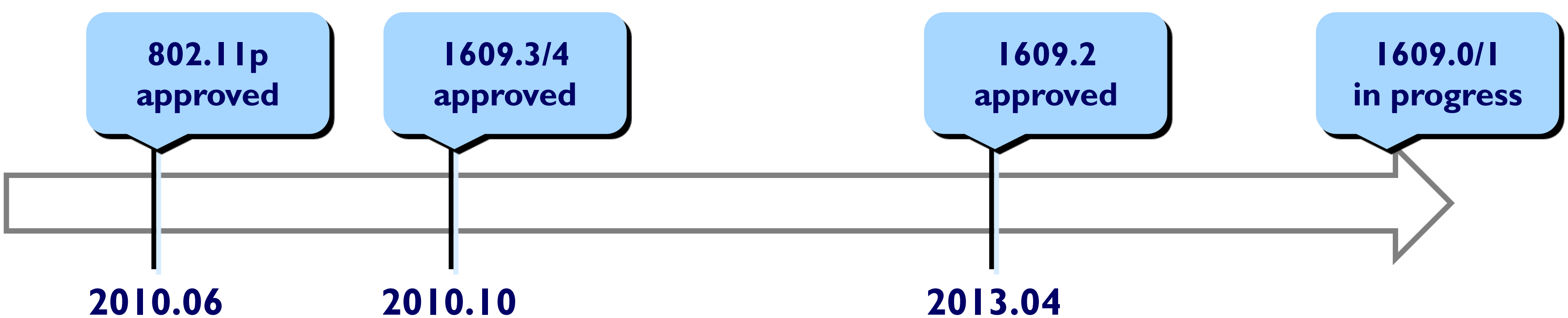
- 이동성을 거의 충족시키지 못하며 주로 실내에서 준정적인 통신 대역폭을 사용하는 IEEE 802.11 a/g 와 달리, WAVE는 높은 이동성을 제공하며 도플러 천이 등의 간섭이 잘 발생하는 실외 환경에 적합

2. WAVE 표준

CITAC
Center for IT & Automobile Convergence

- IEEE 802.11p
  - PHY and MAC layer
  - WLAN based
- IEEE 1609
  - 1609.0 Architecture
  - 1609.1 Remote management service
  - 1609.2 Security
  - 1609.3 Networking services
  - 1609.4 Multi-channel operation
- Dual networking stack
  - IPv6
  - WSMP





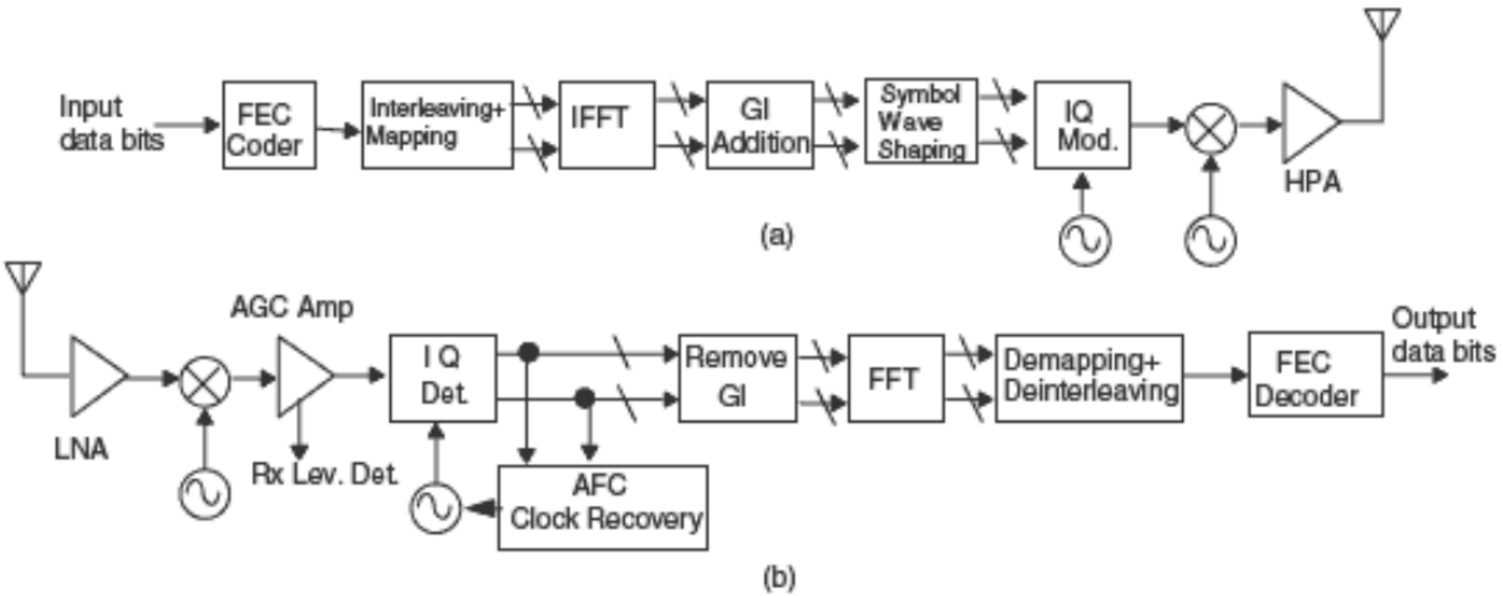
2. WAVE 표준

CITAC Center for IT & Automobile Convergence

IEEE 802.11p (PHY 계층)

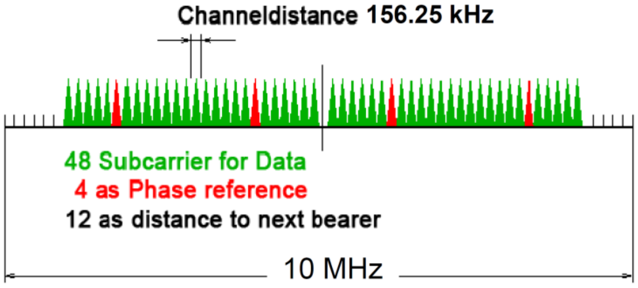
- IEEE 802.11p의 PHY는 5GHz 대역에서 동작하는 IEEE 802.11a PHY로부터 최소한의 변경만을 고려
- OFDM (Orthogonal Frequency Division Multiplexing)
- 20MHz 대역폭 대신 10MHz 대역폭을 이용

- Block diagram of OFDM modem (a) Transmitter, (b) receiver.



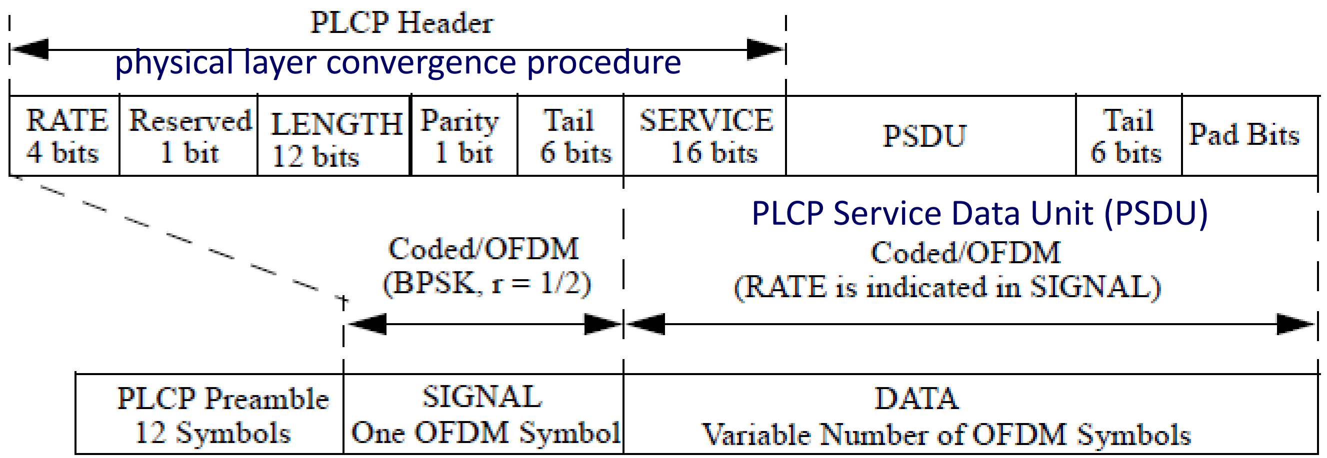
2. WAVE 표준

	IEEE 802.11a	IEEE 802.11p
Symbol duration	4 µs	8 µs
Guard period	0.8 µs	1.6 µs
Subcarrier $\Delta f = 1/T_u$	0.3125 MHz	0.15625 MHz
OFDM subcarriers	52	52
Default Bandwidth	20 MHz	10 MHz
Data rates / Mbps	6, 9, 12, 18, 24, 36, 48, 54	3, 4.5, 6, 9, 12, 18, 24, 27
Frequency Band	5 GHz ISM	5.9 GHz dedicated

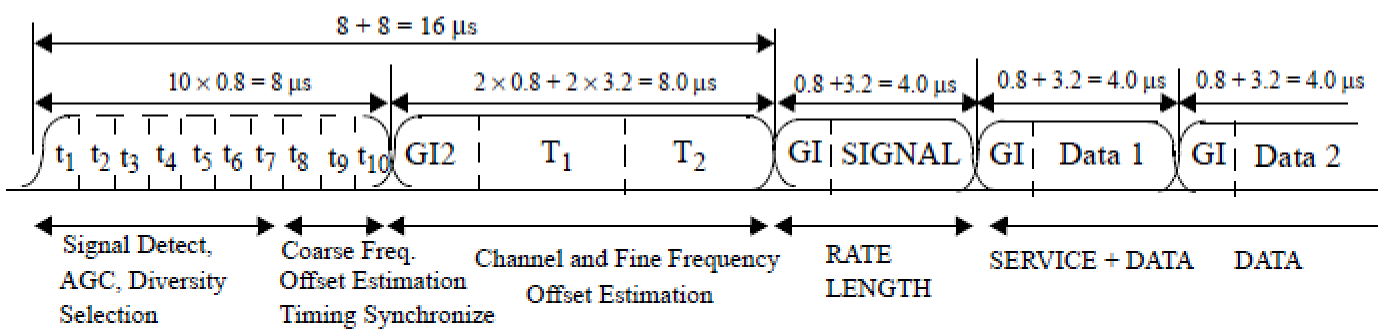


2. WAVE 표준

- Frame format



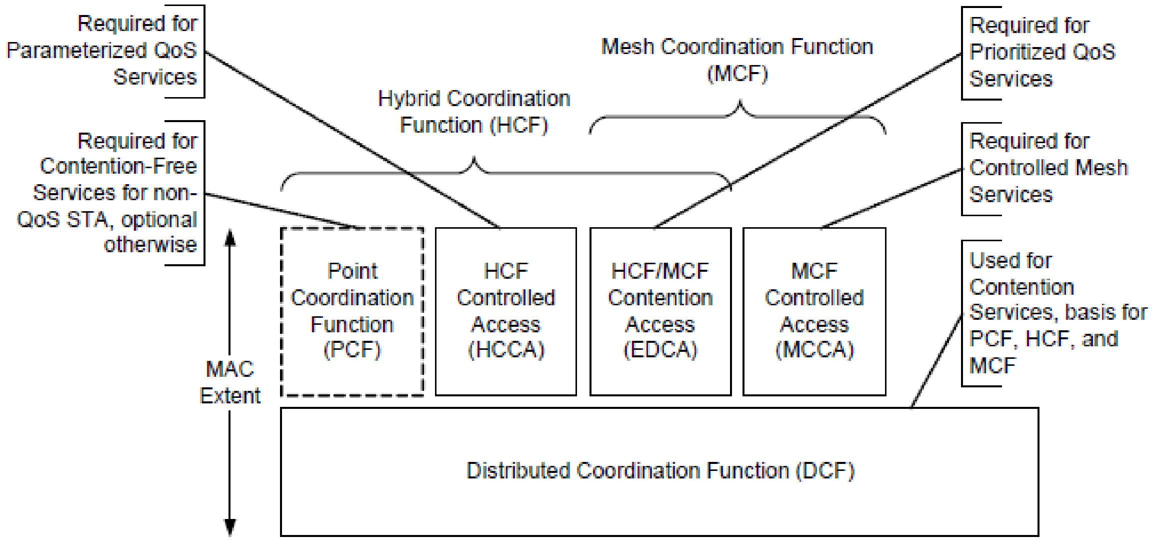
- Preamble structure



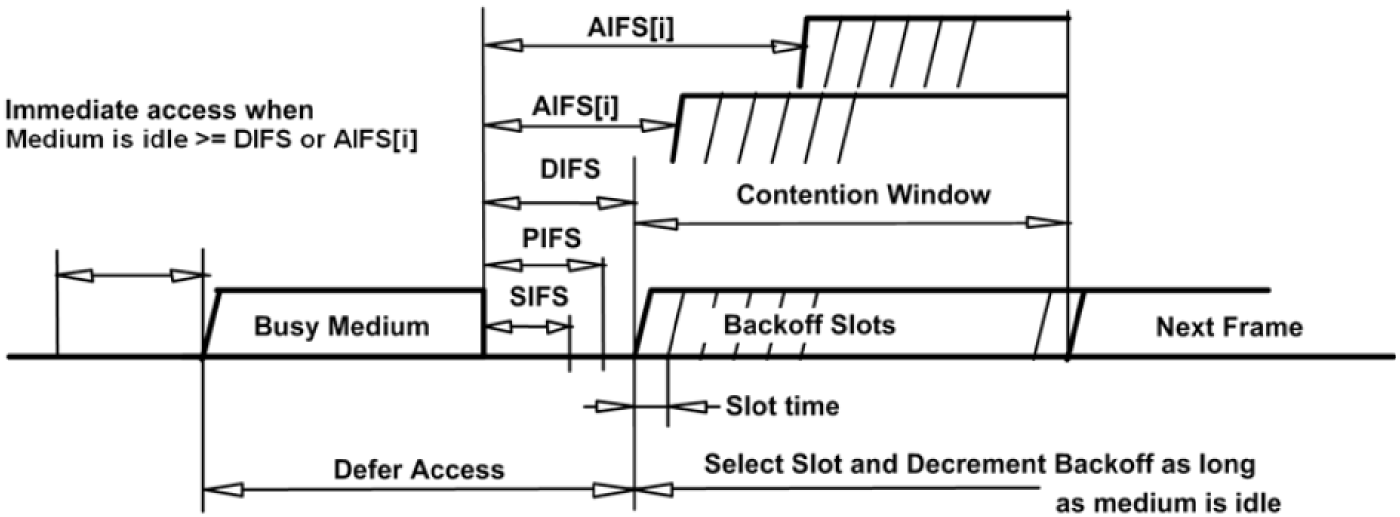
2. WAVE 표준

IEEE 802.11p (MAC 계층)

- Distributed Coordination Function (DCF)
  - Carrier Sense Multiple Access / Collision Avoidance (CSMA/CA)
  - 각 STA의 경쟁에 의한 미디어 접근
- Point Coordination Function (PCF)
  - Point Coordinator 가 존재 → Polling Master → AP
  - Polling을 사용하여 무경쟁 기반의 미디어 접근
  - WAVE에서는 사용하지 않음
- MAC architecture



- DCF (Distributed Coordination Function)



Time Value	IEEE 802.11a	IEEE 802.11p
SlotTime	9 usec	13 usec
SIFS (Short Inter-frame Space)	16 usec	32 usec
DIFS (DCF Inter-frame Space)	50 usec	36 usec

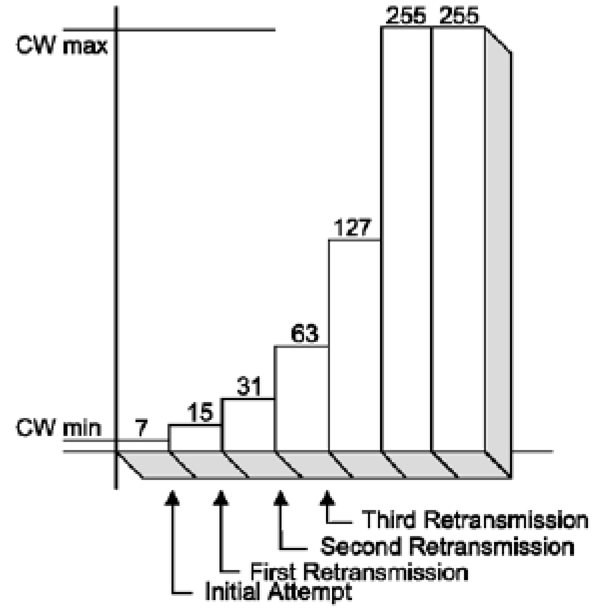
2. WAVE 표준

- Back-off Algorithm

  - 이전의 충돌에 대한 재 충돌확률을 감소시키기 위한 알고리듬
  - Contention Window (CW) 값에 의해 결정되는 랜덤한 값에 SlotTime을 곱한 기간 동안 자신의 전송을 지연

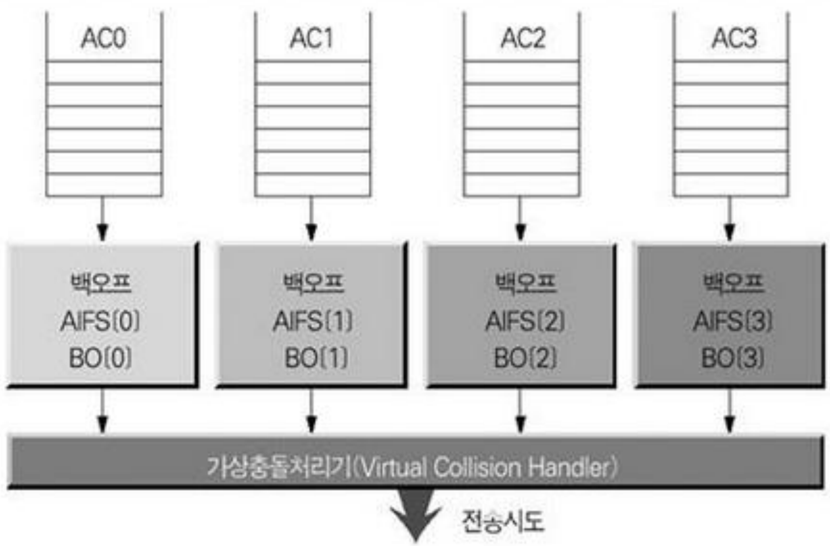
$$\text{Backoff Time} = \text{Random}() \ * \ \text{SlotTime}$$

  - Contention Window 는 충돌 발생시마다 지수적으로 증가됨
  - 재전송 시도가 성공하면, Contention Window는 다시 Minimum Contention Window로 초기화



2. WAVE 표준

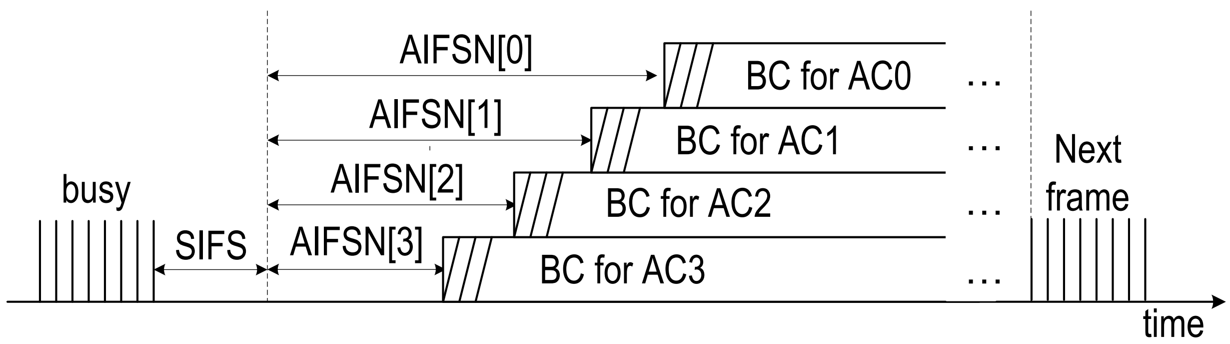
- EDCA (Enhanced Distributed Channel Access)
  - Up to 4 queues, each associated with an Access Category (AC)
  - Head-of-line frame in a queue competes for channel access
    - Competes with frames in other STAs
    - Competes with other queues in same STA



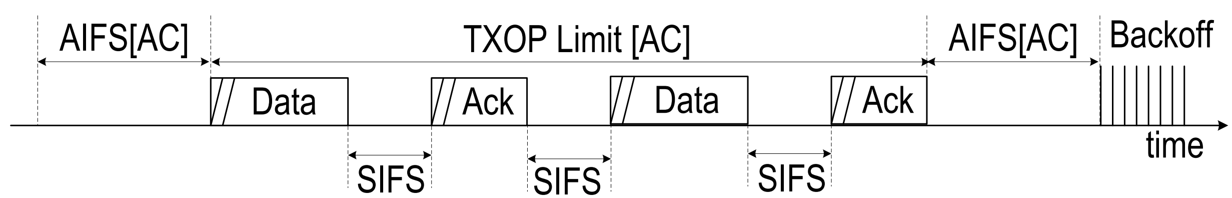
Priority	User Priority (UP)	Access Category (AC)	Designation (informative)
Lowest	1	AC_BK	Background
.	2	AC_BK	Background
.	0	AC_BE	Best Effort
	3	AC_VI	Video
	4	AC_VI	Video
.	5	AC_VI	Video
	6	AC_V0	Voice
Highest	7	AC_V0	Voice

CITAC
Center for IT & Automobile Convergence

- EDCA (Enhanced Distributed Channel Access)
  - Competition governed by
    - Inter-Frame Space parameter (AIFSN)
    - Contention Window parameter

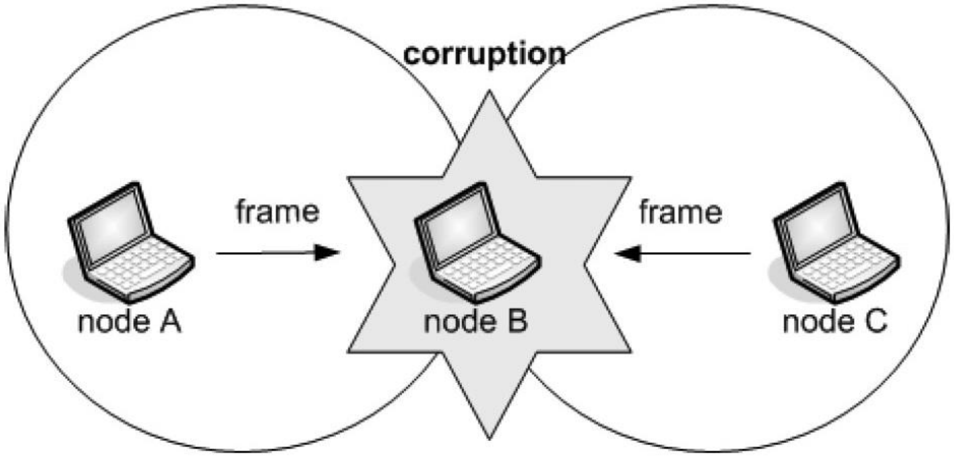


- TXOP (Transmission Opportunity)



2. WAVE 표준

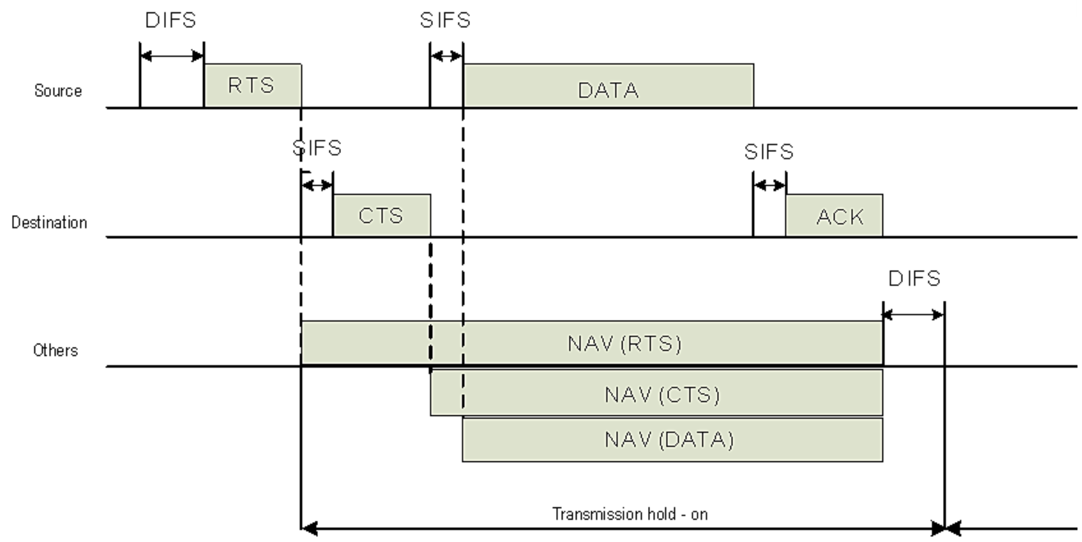
- Hidden Node Problem



- 서로 전파가 닿지 않는 두 차량 (node A & node C)이 두 차량으로부터 모두 전파 수신 가능한 차량 (node B)으로 데이터 전송 시 발생하는 신호 충돌 현상
- node A와 node C는 신호의 충돌 여부를 알 수 없음

2. WAVE 표준

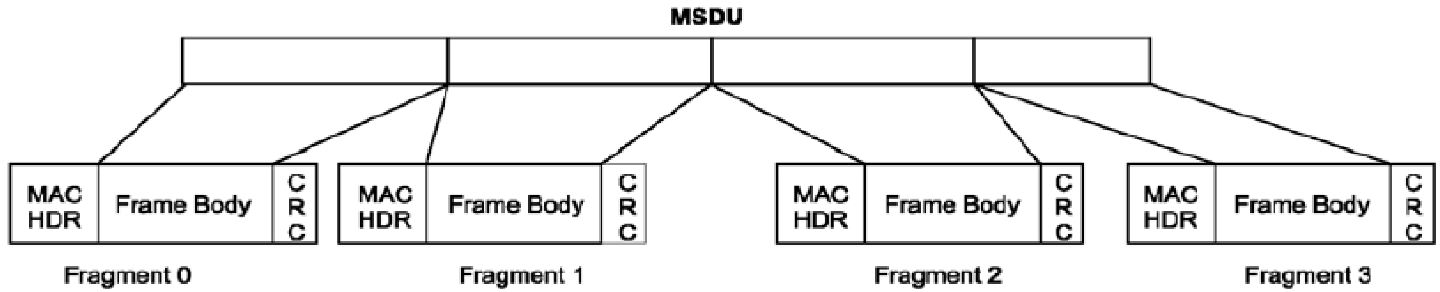
- RTS / CTS



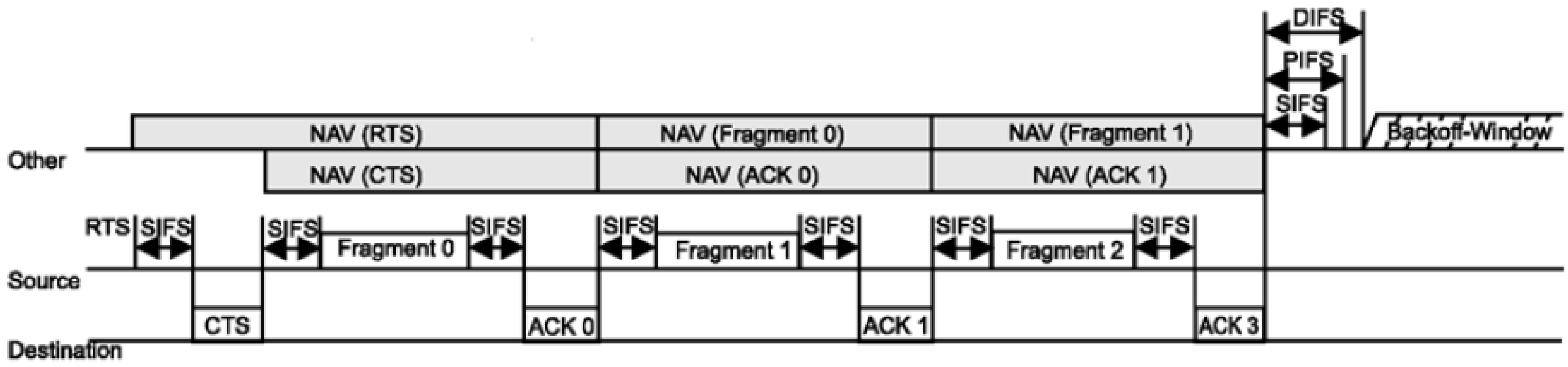
- RTS
  - 패킷의 duration 영역에 DataSendTime + ACKSendTime + CTSSendTime + 3 * SIFS 시간 기록
  - 이를 수신한 다른 단말들은 자신의 Network Allocation Vector (NAV) 타이머를 설정하고 이 기간 동안의 송신을 지연
- CTS
  - RTS 패킷을 수신한 receiver 가 응답
  - 패킷의 duration 영역에 RTS duration Value – (CCTSSendTime + SIFS)
  - 이를 수신한 다른 단말들은 자신의 자신의 Network Allocation Vector (NAV) 타이머를 설정하고 이 기간 동안의 송신을 지연

CITAC
Center for IT & Automobile Convergence

- Fragmentation



- BER 이 높은 환경에서 긴 프레임을 분할 전송함으로써 재전송을 감소
- Unicast 프레임만 분할 가능
- Fragmentation Threshold를 초과할 경우 프레임을 분할

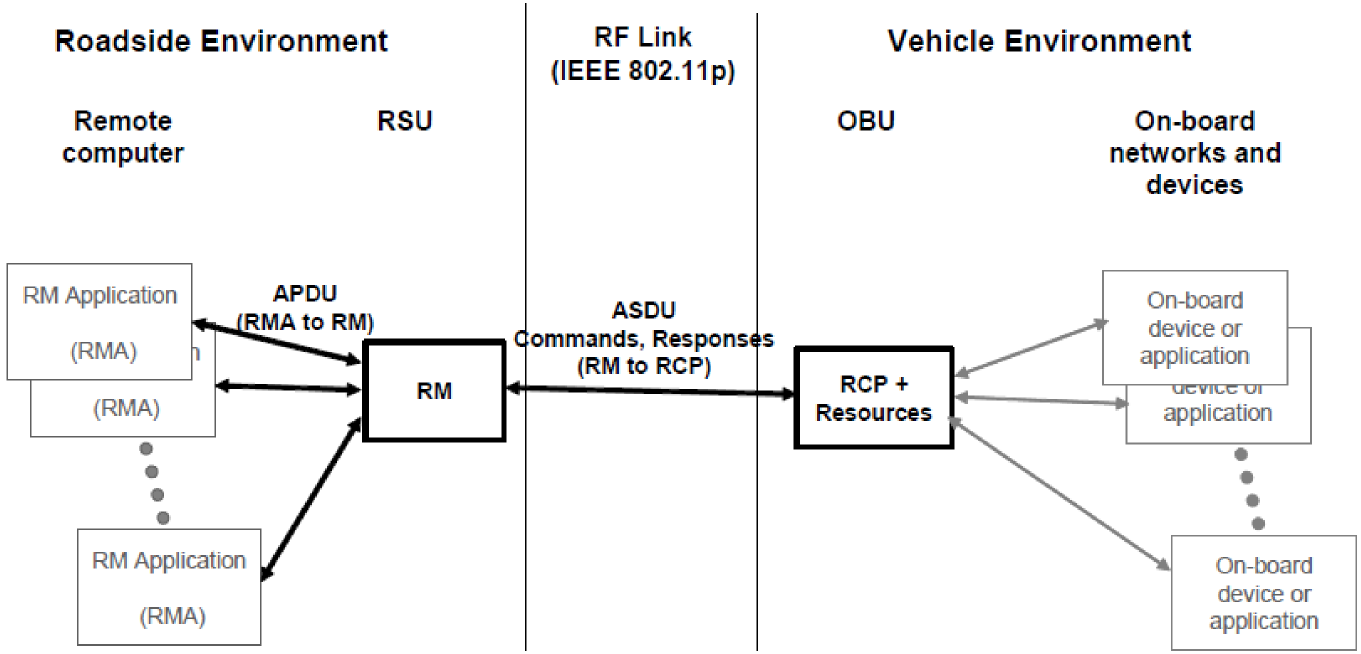


RTS / CTS with fragmented MSDU

2. WAVE 표준

IEEE 1609.1 (Resource Manager)

- IEEE 1609.1은 어플리케이션과 이 어플리케이션이 주어진 자원을 효율적으로 사용할 수 있도록 자원을 관리하는 RM에 관하여 정의
- 대체로 RM은 RSU에, RM과 통신하는 RCP (Resource Command Processor)는 OBU에 위치
- RMA (Resource Manager Application)는 RM를 통하여 RCP와 통신하여 RMA가 필요로 하는 메모리, 사용자 인터페이스, RCP가 관리하는 다른 인터페이스 등의 자원에 엑세스하기 위함
- RM은 마치 RMA의 응용 계층처럼 동작함

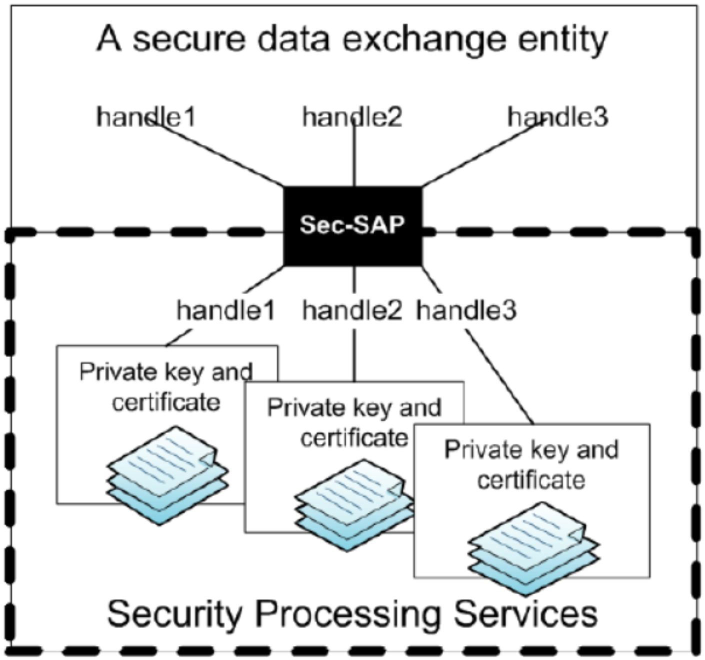


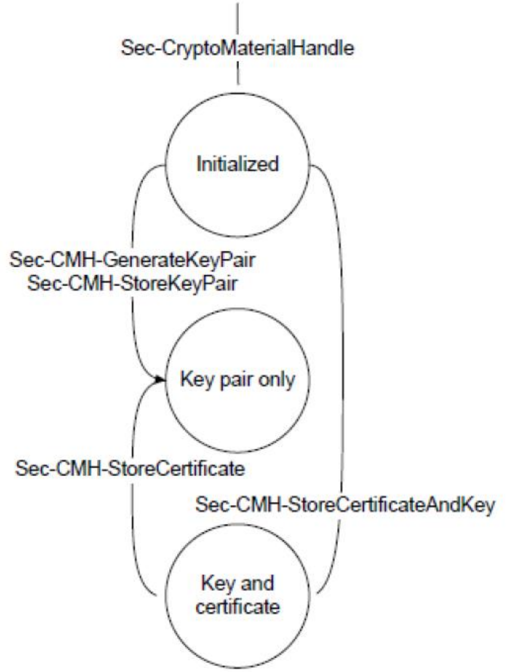
2. WAVE 표준

CITAC
Center for IT & Automobile Convergence

IEEE 1609.2 (WAVE security)

- IEEE 802.11p는 가입과정을 간략화하기 위해 기존의 IEEE 802.11의 인증과 결합절차를 생략 → 보안 문제가 발생
- IEEE 1609.2 표준은 WAVE 네트워크와 어플리케이션을 위해 MAC 상위 계층에서 보안서비스를 제공
- 제공하는 보안 서비스에는 공개키 (Public key)를 이용한 인크립션 (Encryption) 기법과 비익명 인증 (Non-anonymous Authentication) 기법을 이용

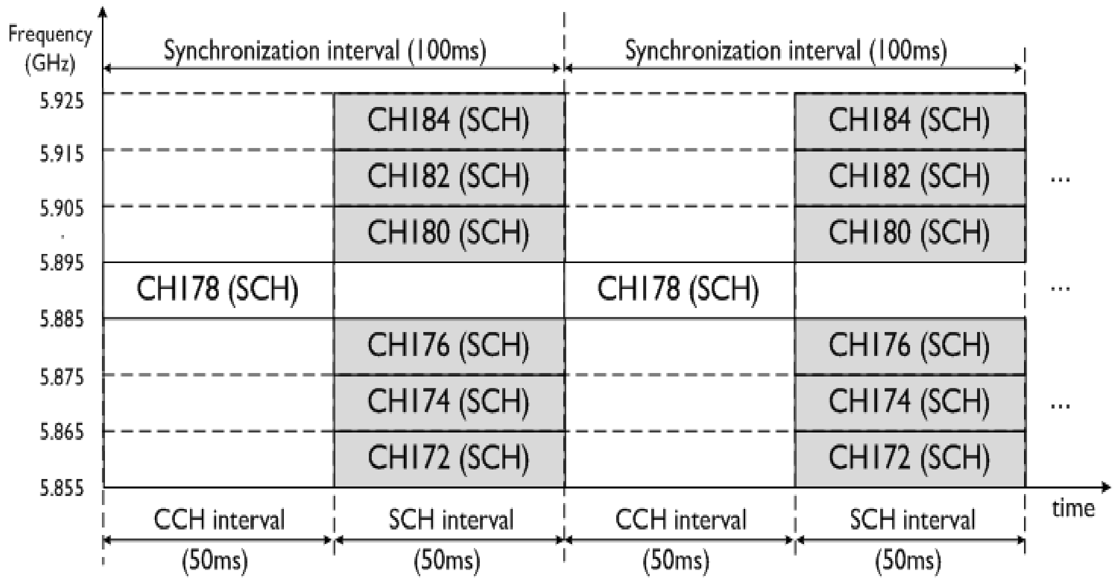




CITAC
Center for IT & Automobile Convergence

IEEE 1609.4 (Multi-channel Operations)

- Channel switching between
- Control channel (CCH) : Management and (high priority) short message
- Service channel (SCH) : general user message and IP traffic

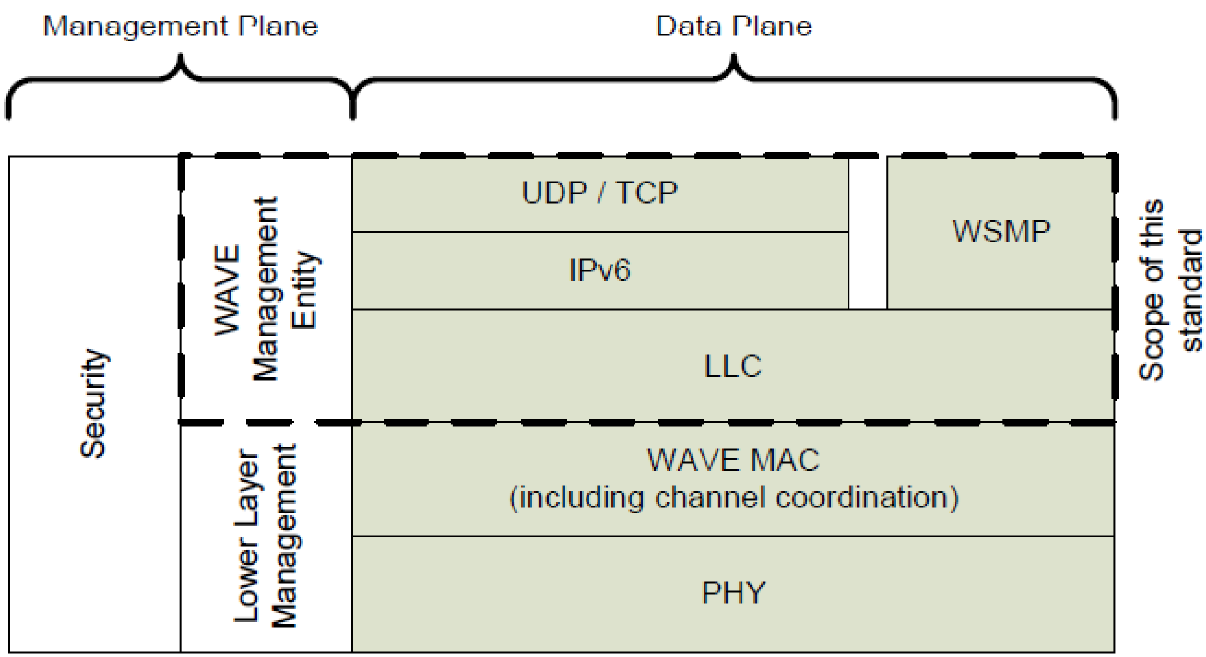


- Data Plane service
  - Channel coordination
  - Channel routing
  - User priority
- Management service
  - Multi-channel synchronization
  - Channel access
  - Vendor-specific action frame
  - Other IEEE 802.11 service
  - MIB maintenance
  - Readdressing

2. WAVE 표준

IEEE 1609.3 (Networking Services)

- Specifies network and transport layer protocols and services that support high-rate, low-latency, multi-channel wireless connectivity.
- 서비스 제공자와 유저 간의 안전한 데이터 교환을 위하여 데이터 전송을 위한 통신 프로토콜에 대한 Data plane과 시스템 구성과 유지 기능을 수행하기 위한 Management plane으로 구성

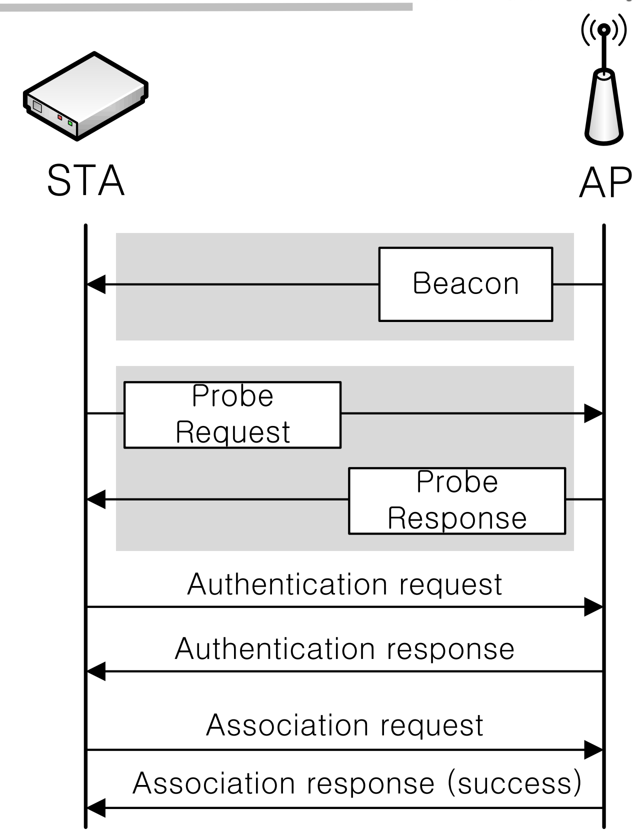


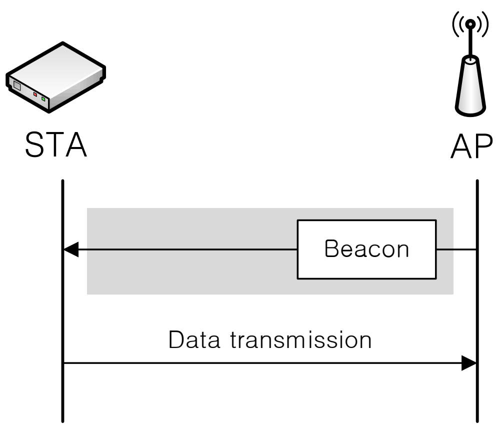
- Key services :
  - LLC
  - IPv6 / UDP / TCP
  - WSMP
  - WME

2. WAVE 표준

Wi-Fi

- 데이터 통신을 위해서는 탐색/인증/결합 절차를 거쳐야 함
- 해당 절차 완료 후 기지국과의 통신 가능
- 단말과 통신 시에는 기지국을 거쳐 통신





WAVE (802.11p)

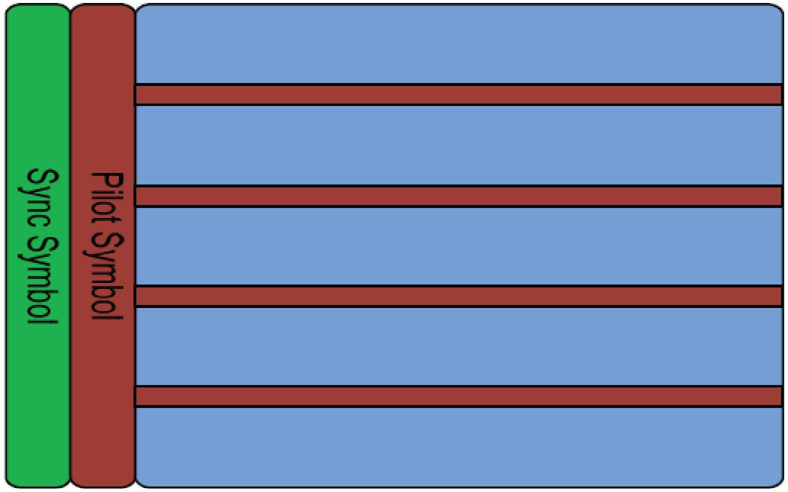
- 탐색/인증/결합 절차 없이 데이터 통신가능
- 단말 간 직접 통신 가능

3. WAVE 개선 사항

CITAC
Center for IT & Automobile Convergence

Channel Estimation

- 두 파일럿 부반송파 간격(2.4MHz, 52개 부반송파 중 4개의 파일럿): coherence bandwidth보다 너무 넓음
  - 50% coherence bandwidth: ~1MHz
- 패킷 전송시간(300 bytes 0.5ms) : coherence time보다 길다
  - 50% coherence time: 0.2ms
- IEEE 802.11p 채널 예측
  - first obtain a wideband channel estimate from pilot symbols, and then monitor the residual channel variation using the pilot subcarriers
  - After the coherence time, the channel estimates obtained from the pilot symbols becomes obsolete
  - The sparse pilot subcarriers are not sufficient to track the channel

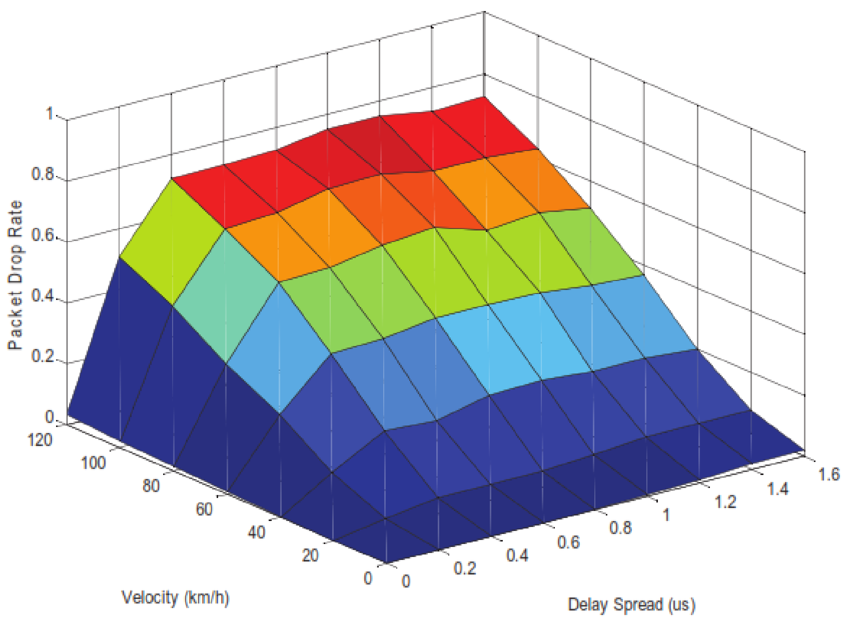


3. WAVE 개선 사항

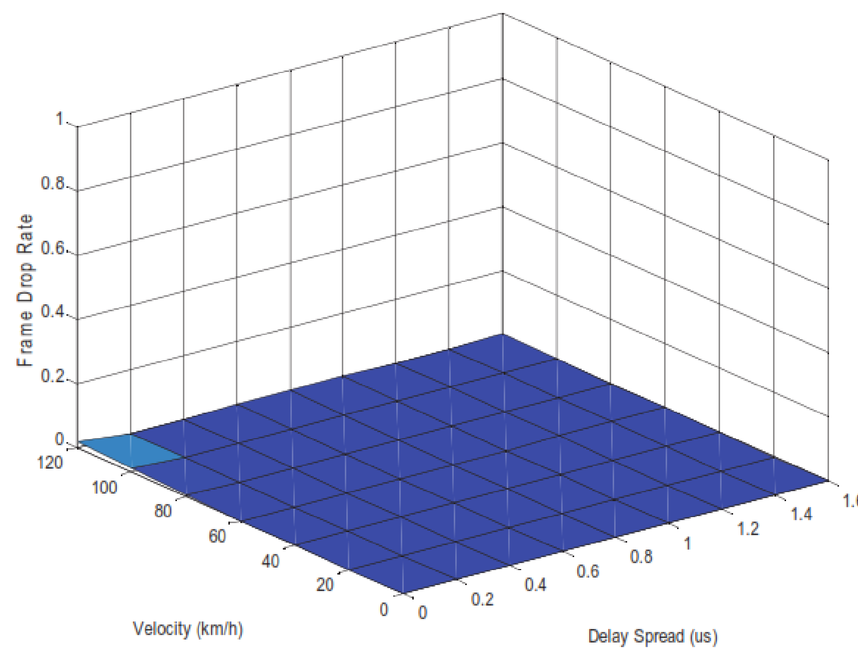
CITAC
Center for IT & Automobile Convergence

Channel Estimation

- One of possible solutions can be: Turbo receiver
  - Iterates between channel estimation and decoding, instead of carrying out the two steps in sequential order
  - Receiver algorithm enhancement and fully compatible with the existing IEEE 802.11p standards



(a) Conventional IEEE 802.11a implementation.



(b) Turbo receiver implementation.

3. WAVE 개선 사항

CITAC
Center for IT & Automobile Convergence

Time Selective Fading without Time Interleaving

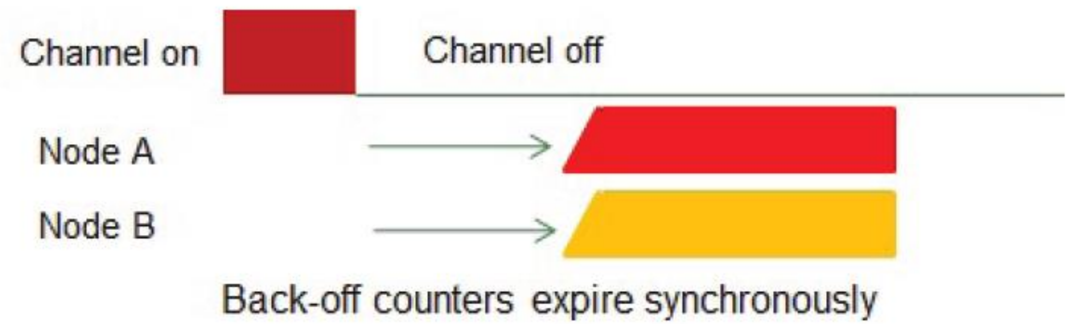
- IEEE 802.11p uses convolutional codes with a short constraint length (7) and no time interleaving is allowed
  - The receiver can reliably decode a particular information bit coded and transmitted earlier in the packet without waiting for the reception of the whole packet
  - One can use the already-decoded bits as pilots for the remaining packets to improve channel estimation
- No time interleaving leads to significant performance degradation in a time selective channel even without channel estimation errors
  - In time-selective channels, if a symbol (or a few adjacent symbols) is in a deep fade, there is a very low probability for the receiver to recover the information bits encoded in the symbol
  - In IEEE 802.11p, the packet length can be longer than the coherence time, which indicates that deep fades can happen within the transmission time of a packet with significant probability
- This problem is well understood in the wireless communication community and can be resolved using a better coding scheme (e.g. Turbo or LDPC code)
- This indeed requests a standard change and is better to be addressed in future versions of V2X

3. WAVE 개선 사항

CITAC
Center for IT & Automobile Convergence

CSMA Behavior at High Node Density

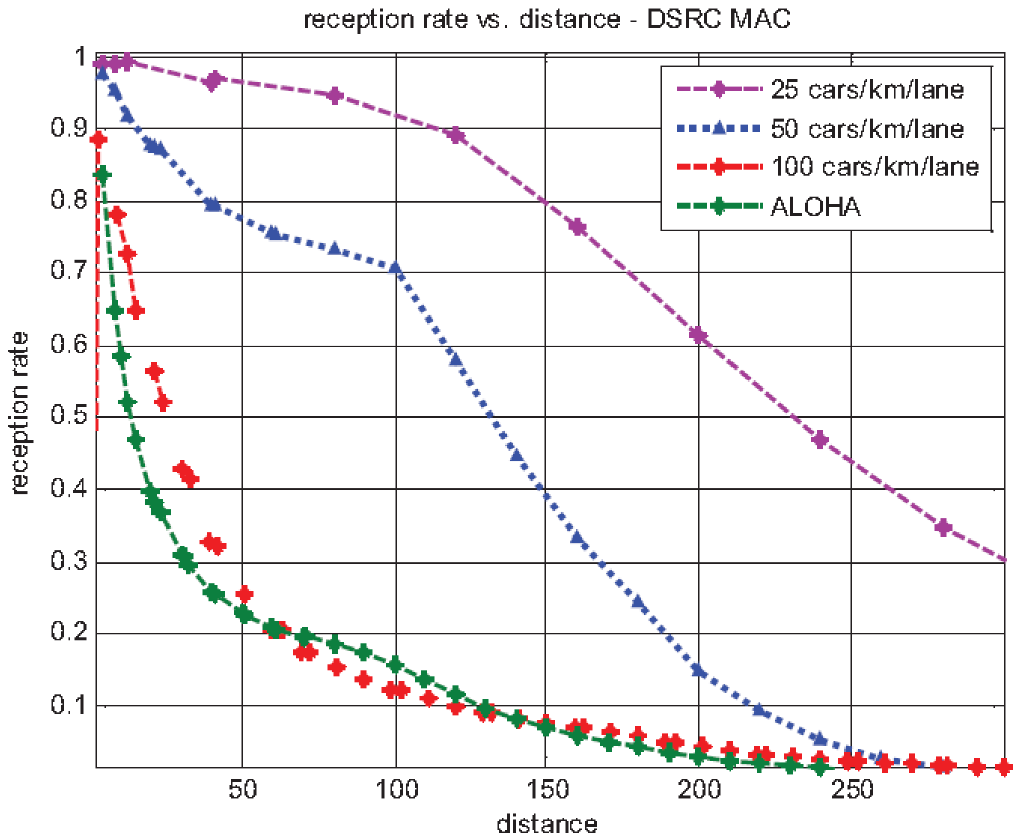
- Vehicle safety communication applications rely heavily on periodic broadcast of basic safety messages (BSM) which contain the positions, velocities, and other information about the vehicles
- IEEE 802.11p uses CSMA/CA and a random back-off procedure to reduce collisions of over-the-air packets
- Synchronous countdown of the back-off timers by any two transmitters within the carrier sense range of each other
- At high densities, many devices observe the channel to become idle at the same moment and start counting down their timers to zero synchronously and then transmit at the same time



3. WAVE 개선 사항

CSMA Behavior at High Node Density

- The performance appears to trend towards an ALOHA–like behavior due to a lack of protection against nearby transmitters transmitting simultaneously



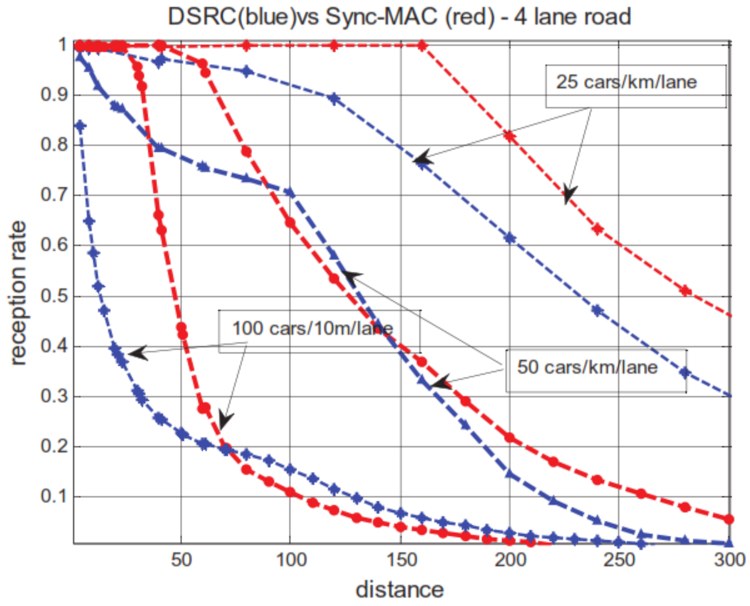
In ALOHA, each transmitter chooses to transmit with a probability that is independent of other transmitters around it implying that there is no guaranteeed protection zone around a transmitter.

Potential Solutions to Congestion Control

- Controlling the transmit powers of the devices to reduce the number of devices synchronously counting down
- Reducing the periodicity of the safety messages
- Increasing the carrier sense threshold
    - The main tradeoff is how to ensure high channel utilization while reducing collisions
- Distributed congestion control mechanism
    - each vehicle dynamically adjusts its transmission parameters in response to the observed channel load (based on channel busy time)
    - identification of the optimal channel load and/or obtaining stable transmit-parameters without oscillations is not yet well understood

Potential Solutions to Congestion Control

- Time-slotted synchronous system with a fixed set of broadcast resources
  - In a time slotted system, a fixed number of broadcast resource slots may occur in a periodic manner
  - Obtain a good spatial pattern of concurrent transmissions and maintain the same configuration for longer durations
- While the current DSRC standard does not specify the need for such synchronization, the addition of such "hooks" into the standard can be beneficial



Reception rate vs. distance, 4-lane road. Comparison of the discovery performance of the synchronous MAC with the DSRC approaches.

CITAC
Center for IT & Automobile Convergence

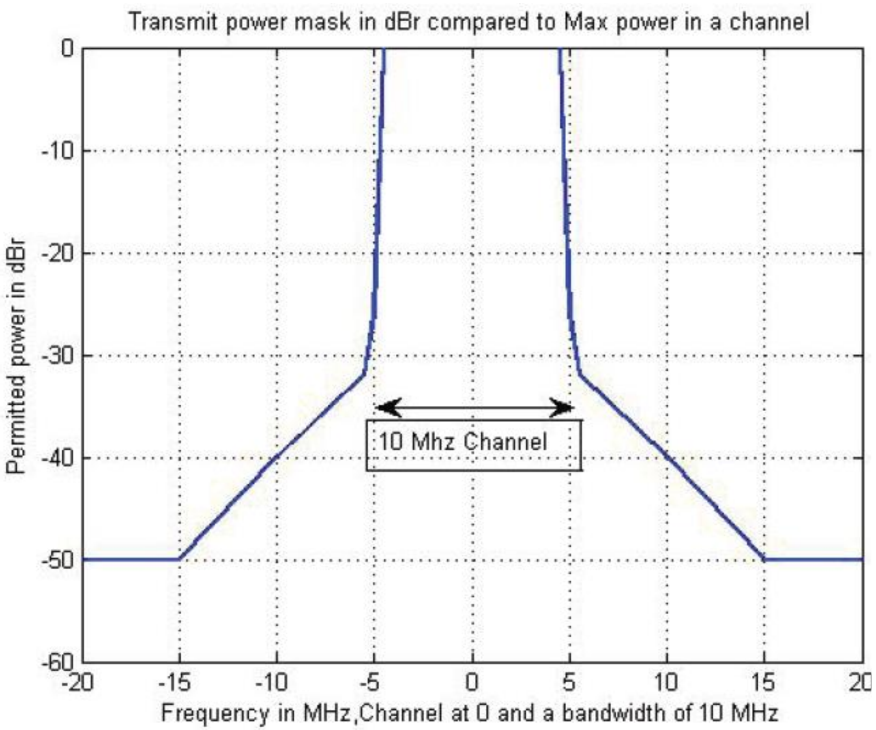
Multichannel Operations in V2X

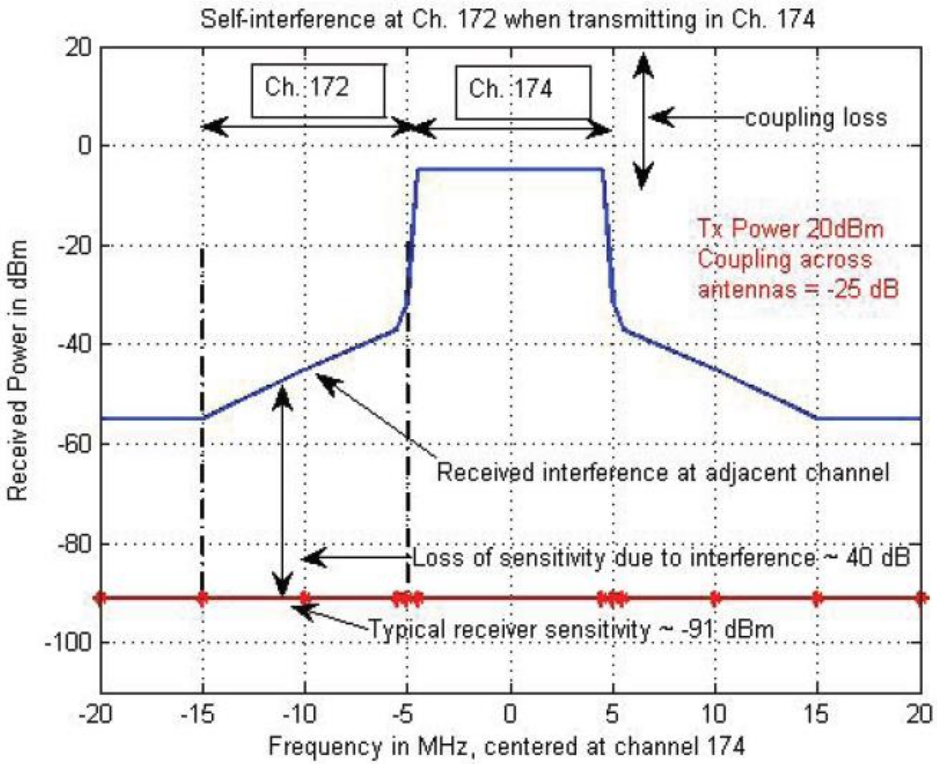
- A main motivation behind such channelization is the ability to utilize the market penetration of existing Wi-Fi chipsets that operate over 20MHz channels
- The original chips can be run 'half-clocked' to achieve a 10 MHz bandwidth and be made more suitable for the highly mobile and frequency selective vehicular channels
- The IEEE 1609.4 MAC extension layer (multi-channel operations) was created to enable the use of multiple channels by the upper layers of a V2X device to support safety and other applications
- For single radio devices:
  - The idea was to use one of the 10 MHz channels - Channel 178 the common control channel (CCH) – to safety messages and use the remaining channels as service channels (SCH) to support point-to-point communications
  - The main issue is the reduced capacity to support the broadcasting of safety messages
  - Highly spectrum inefficient as six of the seven channels are underutilized during the CCH interval, as all radios have to be tuned to receive in CCH

CITAC
Center for IT & Automobile Convergence

Multichannel Operations in V2X

- For multiple radio devices:
  - The industry is seen moving towards a '1609.4 optional' route where all devices use the Channel 172 (different from the CCH channel) for safety broadcasts
  - The reception in the safety channel may be influenced when a vehicle is transmitting over a separate radio channel to support any other application





참고문헌

CITAC
Center for IT & Automobile Convergence

① Scott E. Carpenter, "Inter-Vehicle Communications (IVC): Current Standards and Supporting Organizations", June 2013, [Online:] http://www4.ncsu.edu/~scarpen/Research_files/IVC_scarpenter2013.pdf

② IEEE, 1609 WG – Dedicated Short Range Communication Working Group. [Online:] http://standards.ieee.org/develop/wg/1609_WG.html

③ H. Hartenstein and K. Laberteaux, A Tutorial Survey on Vehicular Ad Hoc Networks, IEEE Communications Magazine 164:171, June 2008.

④ Research and Innovative Technology Assistance (RITA), IEEE 1609 - Family of Standards for Wireless Access in Vehicular Environments (WAVE), U.S. Department of Transportation, [Online:] http://www.standards.its.dot.gov/Factsheets/Factsheet/80

⑤ X. Wu et al., "Vehicular Communications using DSRC: Challenges, Enhancements, and Evolution", IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS/ SUPPLEMENT, VOL. 31, NO. 9, SEPTEMBER 2013

⑥ IEEE, IEEE Std 1609.2-2013 - IEEE Standard for Wireless Access in Vehicular Environments—Security Services for Applications and Management Messages, 26 Apr 2013.

⑦ IEEE, IEEE Std 1609.1-2006 - IEEE Trial-Use Standard for Wireless Access in Vehicular Environments (WAVE) - Resource Manager, 13 Oct 2006.

⑧ IEEE, IEEE Std 1609.3-2010 - IEEE Standard for Wireless Access in Vehicular Environments (WAVE) - Networking Services, 30 Dec 2010.

⑨ IEEE, IEEE Std 1609.4-2010 - IEEE Standard for Wireless Access in Vehicular Environments (WAVE) - Multi-channel Operation, 7 Feb 2011.

⑩ P. Farradyne, Vehicle Infrastructure Integration (VII): VII Architecture and Functional Requirements – Version 1.1, ITS Joint Program Office, U.S. Department of Transportation, 20 Jul 2005.

Center for IT & Automobile Convergence

감사합니다

dshan@knu.ac.kr