Congestion Control in IEEE 802.11p

Date: 2006-09-21

Authors:

Name	Company	Address	Phone	email
Lothar Stibor	Philips	ComNets, RWTH Aachen University, Kopernikusstr. 16, 52074 Aachen, Germany	+49-241-802-0547	lsr@comnets.rwth-aachen.de
Yunpeng Zang	Philips	ComNets, RWTH Aachen University, Kopernikusstr. 16, 52074 Aachen, Germany	+49-241-802-5829	zangyp@ieee.org
Guido R. Hiertz	Philips	ComNets, RWTH Aachen University, Kopernikusstr. 16, 52074 Aachen, Germany	+49-241-802-5829	hiertz@ieee.org
Sebastian Max	Philips	ComNets, RWTH Aachen University, Kopernikusstr. 16, 52074 Aachen, Germany	+49-241-802-0547	max@ieee.org
Hans-Jürgen Reumerman	Philips	Philips Research Laboratories, Weißhausstr. 2, 52066 Aachen, Germany	+49-241-600-3629	hans-j.reumerman@philips.com

Abstract

Congestion control is an essential part of vehicular ad-hoc networks. The ability to deliver packets within an acceptable delay is essential for safety relevant communication for applications like electronic break light, rear end collision warning, etc. As the performance of IEEE 802.11 decreases significantly when the wireless medium is congested, a congestion control concept is needed.

What is congestion?

- Congestion is caused when the offered traffic is larger than the capacity of the network
- EDCA performance drops severely at 50% channel occupancy
- Lots of packet collisions occurring
- Many retransmissions necessary
- Packets discarded due to timeout
- Very high delay

Necessity of Congestion Control

- The WAVE communication protocol is build on control channel (CCH) communication
  - Initiation of the WAVE BSS
  - Safety relevant messages
  - Initiation of Service Channel (SCH) communication
  - Announcement of services
- Contention based CCH access schema (EDCA)
  - Number of collisions grow with number of participating stations
  - EDCA is known to work only with less than approx. 50% medium occupancy time

=> CCH congestion has to be avoided at all cost

Congestion control

- **Three steps needed**
  - Detect congestion
  - Control congestion
  - Avoid collision of high priority messages
- **Cross layer approach**
  - Application layer
  - Medium Access Control Extension layer (MACX)
  - Medium Access Control layer (MAC)
  - Physical layer (PHY)

Detect congestion

CCA busy fraction measurement

- Appropriate measurements already provided from P802.11REVma
- Facility for measuring the fractional duration over which CCA indicated the channel was busy during the measurement duration
  - Unfortunately optional for a STA to support this report
- 7.3.2.21.2 CCA request
  - Requests the measurement for a channel
  - Starting at a time (TSF value, 0 for NOW)
  - For a duration (in TUs, 2Byte field)
- 7.3.2.22.2 CCA report
  - CCA busy fraction = Ceiling (255 * [Duration CCA indicated channel was busy (microseconds)] / (1024 * [Measurement duration (TUs)]))
  - As the CCA busy fraction field is a 1Byte field, a value of 255 represents 100% CCA busy during the measurement.
  - The factor 1024 converts the measurement duration TUs to µs..

Congestion control

MAC extension layer

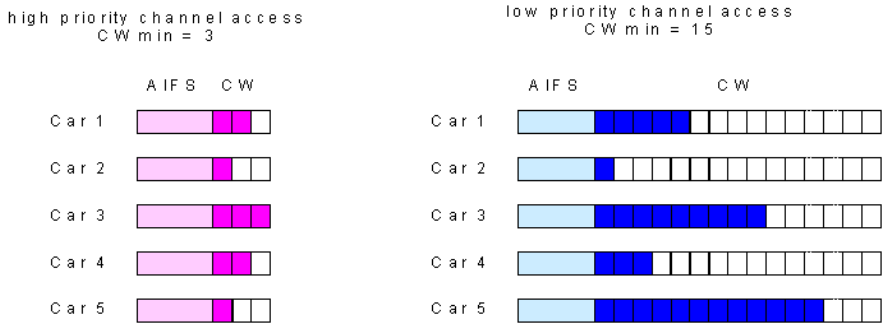
- Rely on measurements from lower layers
  - Consistent measurement crucial for efficient congestion control
  - Measurement needs to be independent from the stations traffic
- Distinguish between control channel and service channels
- Shall control congestion
  - Manipulate transmission queues
  - Set channel access parameters on a per channel basis
- Out of scope of IEEE 802.11p
- Not implemented in IEEE 1609

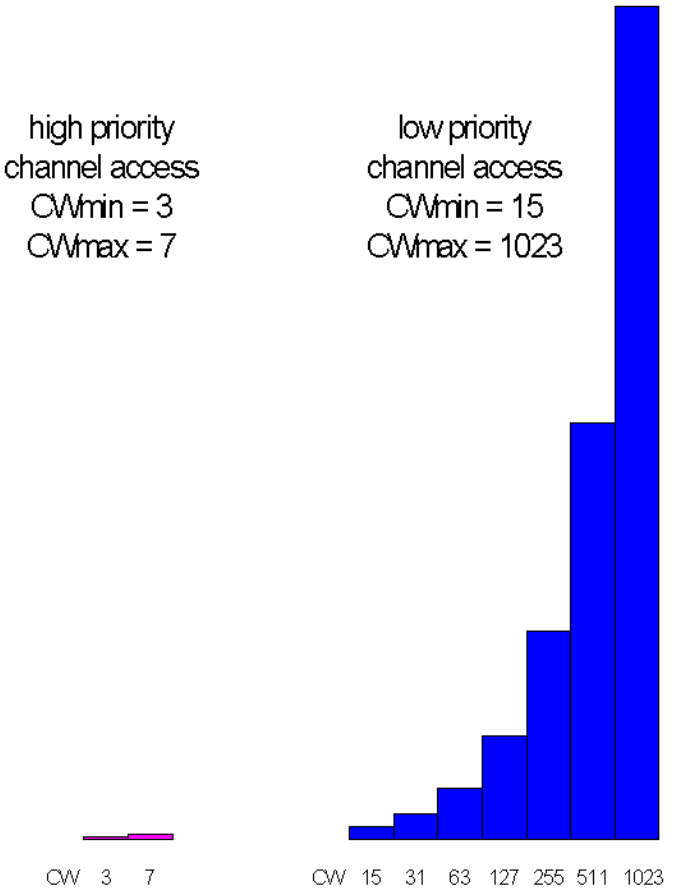
Collision avoidance

EDCA priority mechanism

- Default EDCA parameter set
  - Effective only in giving advantage of high priority versus low priority traffic
  - Default contention window for highest priority traffic is 3
    - Good for prioritization
    - Contra productive in a congested channel
- Highest priority messages are mainly broadcast
  - No missing ACK frames
  - No exponential backoff
  - Contention window does not get enlarged
  - No collision avoidance

Exponential backoff in IEEE 802.11e





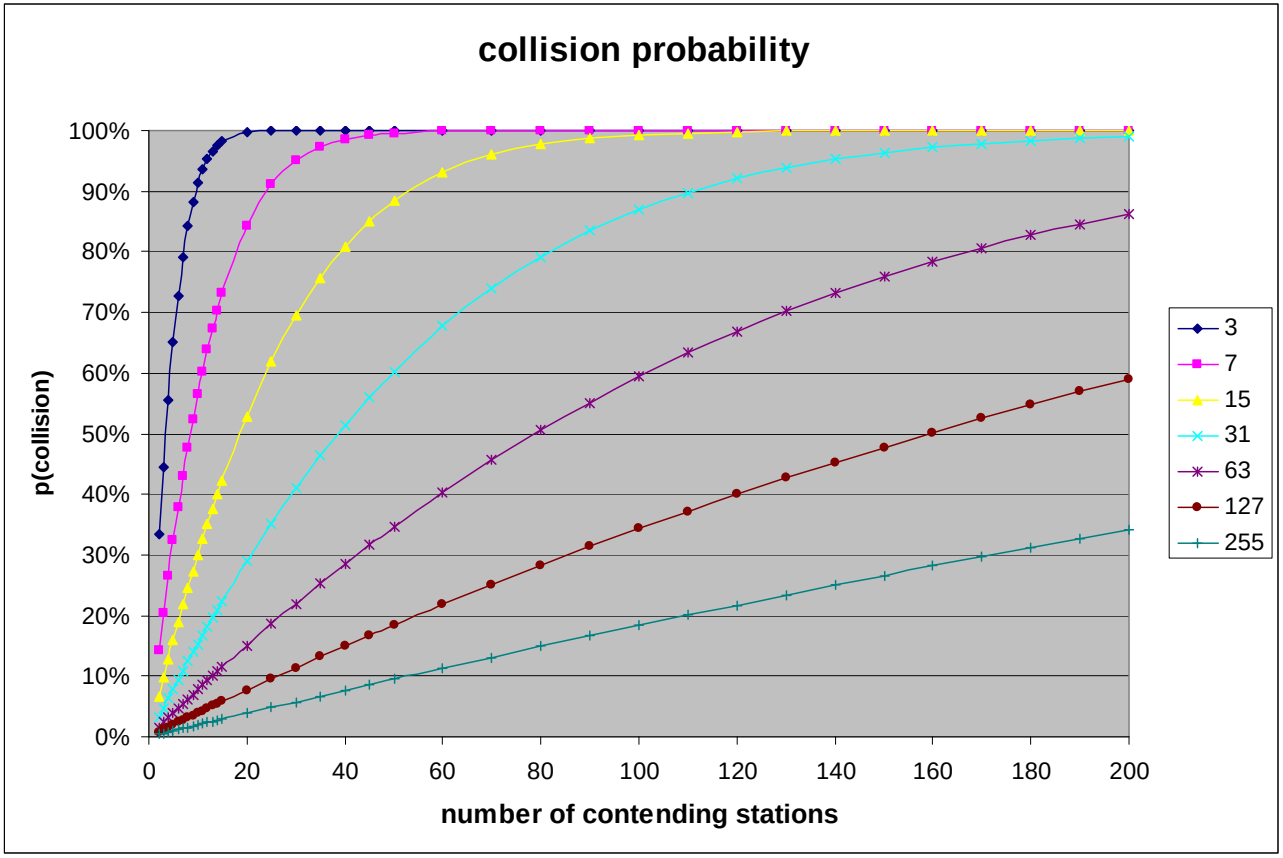
- **High priority**
  - Small initial contention window (CW)
  - Very low delay
  - Very high probability of collision
- **Low priority**
  - Medium initial CW
  - Very large CW after consecutive retries
  - Low probability of collision

Traffic jam scenario

- Transmission power 33dbm (2W)
- PHY mode BPSK ½ (3Mb/s)
- Transmission range > 500m
- Car density > 1 car every 10 meters per lane
- 3 lanes per direction, traffic jam on 3 lanes
- > 150 cars contending for the channel
- Each transmitting a high priority traffic jam warning message (300 byte) ten times a second
- 24kb/s per STA, 3.6Mb/s cumulated traffic

=> Congestion

Collision probability in the congested channel



Collision avoidance in the congested channel

- Detect channel congestion
  - **CCA busy fraction measurement**
- Compare to congestion threshold
  - **Congestion threshold as MIB value**
  - **Similar to RTS/CTS threshold**
  - **Adjustable to upper layer congestion control**
  - **Only needed in absence of a WBSS**
- Prioritize highest priority messages
- Enlarge contention window for highest priority messages
  - **Use congestion aware EDCA parameter set instead of default**

Conclusions

- **Make measurements mandatory**
  - Use existing CCA busy fraction measurement facility
  - Make it mandatory
- **Do regular CCA busy fraction measurements**
  - Fitting to upper layer channel switching
    - Adaptable via MIB values
      - dot11MeasurementDuration
      - dot11MeasurementInterval
- **Avoid high priority message collisions**
  - Switch EDCA parameter set
    - When not member of a WBSS
    - And measured CCA busy fraction is larger than a threshold
      - dot11CongestionThreshold

Motion 1

Move to change subclause 7.3.2.21.2 and subclause 7.3.2.22.2 as stated below and instruct the task group editor to add the statement below to clause 7 of draft P802.11p D1.3 with the appropriate formatting:

Change the third sentence of subclause 7.3.2.21.2 with the following:

STAs operating in WAVE mode shall generate a CCA report in response to a CCA Request. For all other operation modes it is optional for a STA to generate a CCA report in response to a CCA Request.

Change the third sentence of subclause 7.3.2.22.2 with the following:

STAs operating in WAVE mode shall generate this report in response to a CCA Request. For all other operation modes it is optional for a STA to generate this report in response to a CCA Request.

Moved: Lothar Stibor
Second: Dick Roy

Yes: 5
No: 0
Abstain: 0

Motion passes

Motion 2

Move to add the paragraph below after the first paragraph of subclause 9.15 of draft P802.11p D1.3 and add dot11CCAMeasurementDuration and dot11CCAMeasurementInterval as dynamic values to the MIB:

A STA operating in WAVE mode shall monitor the CCA busy fraction of the current channel regularly. The measurement is performed on the current channel every dot11CCAMeasurementInterval for the duration of dot11CCAMeasurementDuration using the CCA request and CCA report as stated in 7.3.2.21.2 and 7.3.2.22.2**.**

Moved: Lothar Stibor

Second: Wayne Fischer

Yes:

No:

Abstain:

After a further discussion this motion was withdrawn by the mover with concurrence of the seconder.

Motion 3

Move to add the paragraph and the table below to the end of subclause 9.15 of draft P802.11p D1.3 and add dot11CongestionThreshold as dynamic values to the MIB:

In the absence of a WBSS, the default EDCA parameter set shall be used for all STAs operating in WAVE mode, as long as the CCA busy fraction of the last measurement is below dot11CongestionThreshold. If the last measurement of the CCA busy fraction is equal or above dot11CongestionThreshold, the EDCA parameter set in table p5 shall be used.

Table p5— congestion aware EDCA parameter set in the absence of a WBSS

ACI	CWmin	CWmax	AIFSN	TXOP Limit
0	aCWmax	aCWmax	9	1
1	aCWmax	aCWmax	6	1
2	aCWmax	aCWmax	3	1
3	17*aCWmin	aCWmax	2	0

Moved: Lothar Stibor
Second: Guenael Strutt

Yes: 1
No: 2
Abstain: 3

Motion failed