MACAW : A Media Access Protocol for Wireless LAN's

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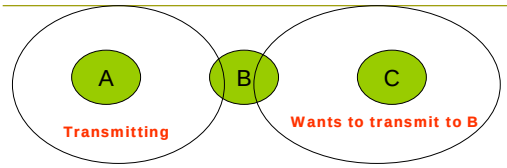
Introduction

- Based on MACA, a Multiple Access Collision Avoidance protocol.
- Initial attempt to deal with WLAN challenges.
- Four key main observations:
  - The relevant contention is at the receiver not the sender.
  - Congestion is location dependent.
  - Learning about the contention level must be a collective enterprise.
  - The media access protocol should propagate congestion information explicitly.

Background

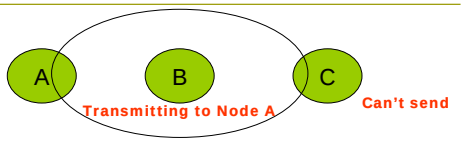
- Developed in Palo Alto Research Center-Xerox Corporation.
- All experiments have been done in noise-free testing environment.
- Multiple access approach is chosen
  - It is more robust, than token based approach.
  - The high mobility of WLAN nodes, will initiate frequent token hand-offs or recovery in token-based systems.

Hidden Terminal



- Station B can hear both A and C, but A and C can't hear each other.
- Happens when station C attempts to transmit while A is transmitting to B.
- Station "A" is hidden from station C.

Exposed Terminal



- Happens when station B is transmitting to A when C attempts to transmit.
- Assuming no interference effect, station C should defer transmitting only if it want to transmit to B.
- Carrier sense provides information about potential collision at the sender, but not at the receiver.

MACA

- Alternative to traditional CSMA
- Uses two types of short messages
  - Request to Send (RTS)
  - Clear to Send (CTS)
- They contain the length of the data transmission.
- Neighbors hearing RTS
  - Defer till CTS would have finished.
- Neighbors hearing CTS
  - Defer till the end of expected data trans.

MACA continue …

- Stations that hear RTS but not CTS can commence transmission.
- Hidden Terminal:
  - C hears B CTS message.
- Exposed Terminal
  - C hears B RTS message.
- If a station did not get a CTS message for its RTS, a collision is assumed after a timeout period.
- Another transmission is scheduled using BEB (Binary Exponential Back-off).

BEB (Binary Exponential Back-Off)

- Retransmission occur if and only if a station does not receive a CTS in response.
- Back-off then retransmit.
- Whenever a CTS is received
  - Back-off counter BO = F_{dec} (BO)
- Whenever a CTS is not received
  - Back-off counter BO = F_{inc} (BO)
- $F_{dec} = BO_{min}$
- $F_{inc}(x) = MIN\ [2x, BO_{max}]$

MACAW - Goals

- A media access control
  - Deliver high network utilization
  - Provide fair access to the media.
- If the goals are not compatible, fairness has a higher priority over optimal total throughput.

MACAW- Back-off Algorithm

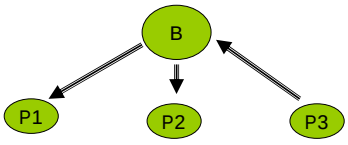
- It is very likely that the least-backed-off station will "win" the bandwidth again.
- The problem caused because there is no sharing of the collision experience.
- **Solution** : Add and extra header to the packets contains current BO value.
- After each successful transmission all pads have the same BO value.
- Use MILD (Multiple increase Linear Decrease) to adjust BO values
  - $F_{inc}(x) = MIN[1.5x, BO_{max}]$
  - $F_{dec}(x) = MAX[x\text{-}1, BO_{min}]$

MACAW-Back-Off Alg. Results

	BEB	BEB copy
P1-B	48.5	23.82
P2-B	0	23.32

	BEB copy	MILD copy
P1-B	2.96	6.10
P2-B	3.01	6.18
P3-B	2.84	6.05
P4-B	2.93	6.12
P5-B	3.00	6.14
P6-B	3.05	6.09

MACAW – Multiple Stream Model



- Using a single queue, Outgoing streams gets half of the bandwidth, the other half for ingoing stream
- We want to teat all streams equally
- Implemented by keeping, in each station, separate queues for each stream and running the back-off algorithm independently for each queue.

MACAW- MSM Results

	Single Stream	Multiple Stream
B-P1	11.42	15.07
B-P2	12.34	15.82
P3-B	22.74	15.64

MACAW – Basic Message Exchange

- MACA uses RTS-CTS-Data model
- MACA recovers from errors by the transport layer
  - Slow
- **Solution** : use RTS-CTS-Data-ACK
- ACK is returned to the sender after immediately upon completion of data reception.

MACAW – Basic Message Exchange

- ACK was not received, retransmit (RTS)
  - Receiver :
    - Data received already, Send ACK
    - Otherwise, send CTS
  - Sender :
    - Increase BO after RTS transmission and no CTS or ACK
    - ACK received : decrease BO.
    - CTS received : BO is not changed.

Error Rate	RTS-CTS-DATA	RTS-CTS-DATA-ACK
0	40.41	36.76
0.001	36.58	36.67
0.01	16.65	35.52
0.1	2.48	9.93

MACAW - DS

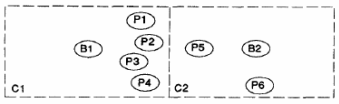
- In the exposed terminal, station C is free to transit if it hears CTS
- If B is transmitting, no CTS
  - C can't tell if RTS-CTS was successful
  - C keeps trying and increasing its BO
- **Solution** : CSMA , Data-Sending packet (DS)
- Every station that hears this packet, defer its transmission
- DS holds the transmission length information

MACAW – Multicast

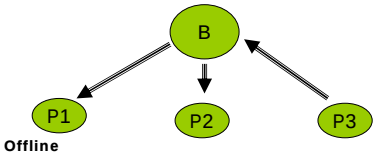
- Want to send a multicast message
- Multiple receivers CTS could collide
- **Solution** : use a special type of RTS followed by Data directly
- Problem : only stations near the transmitter will defer
- This is similar to the problem with CSMA

MACAW – Back-off Alg. Revisited

- Congestion is not homogenous.



- Border stations overhear adjacent cell's BO



MACAW– Back-off Alg. Revisited

- **Solution** : separate BO for each stream
- All stations attempting to communicate with the same receiving station should use the same back-off value.
- Back-off value
  - Copied between stations
  - Separate BO for each station
  - BO of both ends in each packet header

	Single backoff	Per-destination backoff
B1-P2	3.79	8.98
P2-B1	3.78	8.84
B1-P3	3.62	8.68
P3-B1	3.43	8.41

MACAW – Performance Evaluation

- Using MACAW over MACA yielded an improvement of over 37% in throughput.
- MACAW has yielded a “fairer” division of throughput.
- MACAW is able to cope with highly non-homogenous congestion, and can shield un-congested neighbors fro losing too much throughput due to the presence of a congested neighbor.

MACAW– Performance Evaluation

MACA	RTS-CTS-DATA	53.07
MACAW	RTS-CTS-DS-DATA-ACK	49.07

	MACA	MACAW
P1-B1	9.61	3.45
P2-B1	2.45	3.84
P3-B1	3.70	3.27
P4-B1	0.46	3.80
B1-P1	0.12	3.83
B1-P2	0.01	3.72
B1-P3	0.20	3.72
B1-P4	0.66	3.59
P5-B2	2.24	7.82
B2-P5	3.21	7.80
P6-B3	28.40	25.16

	MACA	MACAW
P1-B1	0.78	2.39
P2-B1	1.10	2.72
P3-B1	0.22	2.54
P4-B1	0.06	2.87
P5-B3	18.17	14.45
P6-B2	6.94	14.00
P7-B4	23.82	19.18

Throughput measured by Packets/sec

Future Design Issues

- ACK only if requested
  - Piggy-backed
  - Selective ACK
  - Use NACK
- Find answers to the problems that left unsolved
- Definition of fairness in wireless networks

Comparison between S-MAC and MACAW

MACAW	S-MAC
Fairer bandwidth allocation	Reducing energy consumption
Targets mobile stations	Specific for wireless sensor networks
1994	2004
Rely on Virtual Carrier sense	Rely on both
One ACK for data (long message)	Sends in burst, ACK every data fragment

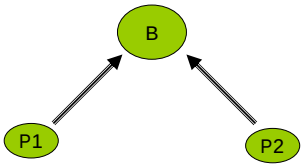
Questions

Critique

- Authors should have compared their approach to other MACA-improved protocols
- Authors did only compare the network throughput without any regard to computational overhead or power consumption added in their adjustments
- Authors did not specify the likelihood of some scenarios, in other words, if a specific adjustment to the algorithm will benefit the overall performance.
- Due to the fact that some problems were left unsolved or partially solved, what is the likelihood of theses problems to occur.

MACAW- Back-off Algorithm

- Scenario where all the stations are in range of each other and two stations are sending data to the base station, and each of them can produce traffic to consume all the bandwidth.



MACAW - RRTS

- The only way B1 can successfully initiate a transfer is when its RTS arrives between successful data transmissions.
  - P1 is deferring because of P2 DS message.
- DS does not solve this problem, because neither B1 nor B2 can hear other messages exchange.

MACAW– RRTS Solution

- **Solution** : RRTS Request-for-RTS.
- Whenever station receive RTS, which can not reply to
  - Send RRTS after the transmission period in DS

	no RRTS	RRTS
B1-P1	0	20.39
P2-B2	42.87	20.53

- Another problem not solved