A Novel MAC Protocol with Fast Collision Resolution for Wireless LANs

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Outline

- Introduction
- Fast Collision Resolution (FCR)
  - FCR algorithm
  - Fairly Scheduled FCR (FS-FCR) algorithm
- Performance Evaluation
- Discussion and Conclusion

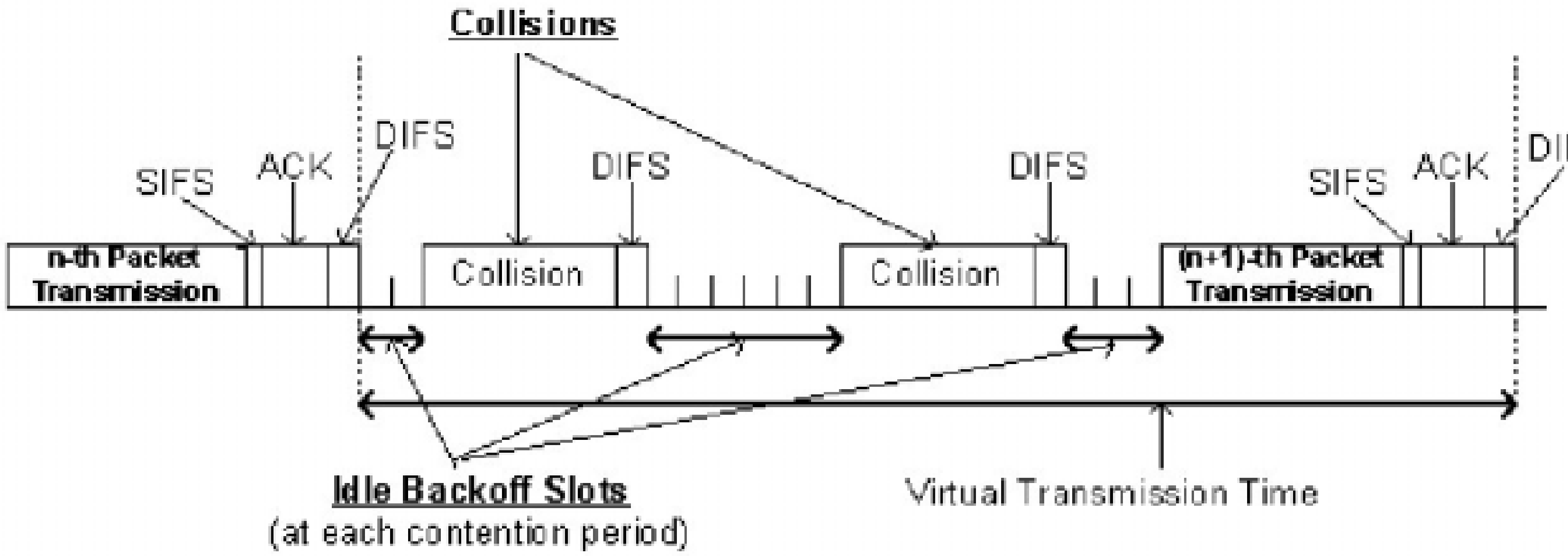
Introduction

- MAC algorithm in WLAN can be classified into
  - Contention-based MAC protocol
  - Reservation-based MAC protocol
- Contention-based MAC protocol
  - usually used in a distributed network architecture
  - suitable for bursty data traffic under low network load
  - easy to implement
  - usually lack of QoS support

Introduction (cont.)

- CSMA/CA
  - the basis of the MAC protocol for IEEE 802.11
  - Not suitable for many active (data transmission) modes
    - Due to the high contention collision rate
    - Need an efficient collision resolution algorithm
      - Adjust the contention window size and randomly chosen back-off values [2]
      - Actively inform others of the busy channel status [3]
      - The contention information appended on the transmitted packets [11,12]

Basic Operations of CSMA/CA



Basic Operations of CSMA/CA (cont.)

- two major factors affecting the throughput
  - Transmission failures
  - The idle slots due to back-off at each contention period
- Based on previous figure, we can obtain the expression for the throughput

$$\rho = \frac{\bar{m}}{E[N_c](E[B_c] \cdot t_s + \bar{m} + DIFS) + (E[B_c] \cdot t_s + \bar{m} + SIFS + ACK + DIFS)}$$

$$\rho_{best} = \frac{\bar{m}}{(\bar{m} + SIFS + ACK + DIFS)}$$

Some discussions and ideas

- Small random back-off timer for the station which has successfully transmitted a packet at current contention cycle
  - Reducing the average number of idle slots

- Large random back-off timer for stations that are deferring their packet transmissions at current contention period
  - Decreasing the collision probability at subsequent contention periods

Some discussions and ideas (cont.)

- Fast change of back-off timer for a station according to its current state
  - Transmitting successful
    - When a station transmit a packet successfully, its next back-off timer should be set small.
  - Deferring
    - When a station is deferring, then its random back-off timers should be large to avoid the possible collision.

Fast Collision Resolution (FCR)

- Use much smaller initial (minimum) contention window size *minCW* then the IEEE 802.11 MAC
- Use much larger maximum contention window size *maxCW* then the IEEE 802.11 MAC
- Increase the contention window size of a station when it is in either collision state and deferring state
- Reduce the back-off timers exponentially fast when a prefixed number of consecutive idle slots are detected.

FCR (cont.)

- When to change the contention window size?
  - IEEE 802.11: when transmission failure occurred
  - FCR: when a station has packets to transfer

- Four states in a station which using FCR
  - Back-off procedure
    - linearly or exponentially decrease
  - Transmission failure (packet collision)
    - $CW=\min(maxCW, CW*2)$
  - Successful packet transmission
    - $CW=minCW$
  - Deferring state
    - $CW=\min(maxCW, CW*2)$

Example of IEEE 802.11 MAC with Binary Exponential Back-off

0	1	2	3	4	5	6	7	8	9	Station Number
1(7)	3(7)	2(7)	7(7)	2(7)	6(7)	3(7)	4(7)	1(7)	6(7)	Contention Begins
0(7) 8(15)	2(7)	1(7)	6(7)	1(7)	5(7)	2(7)	3(7)	**0**(7) 14(15)	5(7)	Collision on station 0 & 8
7(15)	1(7)	**0**(7) 4(15)	5(7)	**0**(7) 9(15)	4(7)	1(7)	2(7)	13(15)	4(7)	Collision on station 2 & 4
6(15)	**0**(7) 10(15)	3(15)	4(7)	8(15)	3(7)	**0**(7) 5(15)	1(7)	12(15)	3(7)	Collision on station 1 & 6
5(15)	9(15)	2(15)	3(7)	7(15)	2(7)	4(15)	**0**(7) 3(7)	11(15)	2(7)	Successful Packet Transmission on station 7

* Each item indicate: Backoff Timer B_i (Contention Window Size)

Example of FCR

0	1	2	3	4	5	6	7	8	9	Station Number
1(3) 1(7)	0(3) 3(7)	2(3) 2(7)	1(3) 7(7)	2(3) 2(7)	2(3) 6(7)	3(3) 3(7)	3(3) 4(7)	1(3) 1(7)	0(3) 6(7)	Collision on 1 & 9
0(7) 8(15)	2(7) 10(15)	1(7) 2(15)	6(7) 1(15)	1(7) 12(15)	5(7) 4(15)	2(7) 15(15)	3(7) 6(15)	0(7) 14(15)	5(7) 3(15)	Collision on 0 & 8
7(15) 22(31)	9(15) 18(31)	1(15) 28(31)	0(15) 1(3)	11(15) 5(31)	3(15) 17(31)	14(15) 11(31)	5(15) 9(31)	13(15) 14(31)	2(15) 23(31)	Success on 3
21(31) 40(63)	17(31) 9(63)	27(31) 38(63)	0(3) 3(3)	4(31) 58(63)	16(31) 24(63)	10(31) 17(63)	8(31) 20(63)	13(31) 44(63)	22(31) 1(63)	Success on 3
39(63) 100(127)	8(64) 55(127)	37(63) 29(127)	2(3) 5(7)	57(63) 111(127)	23(63) 46(127)	16(63) 81(127)	19(63) 30(127)	43(63) 9(127)	0(63) 1(3)	Success on 9
99(127) 67(255)	54(127) 29(255)	28(127) 189(255)	4(7) 11(15)	110(127) 55(255)	45(127) 210(255)	80(127) 160(255)	29(127) 240(255)	8(127) 120(255)	0(3) 2(3)	Success on 9

* Each item indicate: Backoff Timer B_i (Contention Window Size)

Fairly Scheduled FCR (FS-FCR)

- IEEE 802.11 MAC exhibits inherent unfairness characteristics [21,25,27], FCR make things worse.
- Using a modification of the Self-Clocked Fair Queuing (SCFQ) [13,27]
  - Dynamically controlling the maximum successive transmission period

FS-FCR (cont.)

- Each arriving packet to the queue of a station is tagged with a service tag before it is placed in the queue.
- When the k-th packet of station i arrives at the queue of the station, a service tag is assigned as followed:

$$F_i^k = \max\{v(a_i^k), F_i^{k-1}\} + \frac{L_i^k}{\phi_i}$$

FS-FCR (cont.)

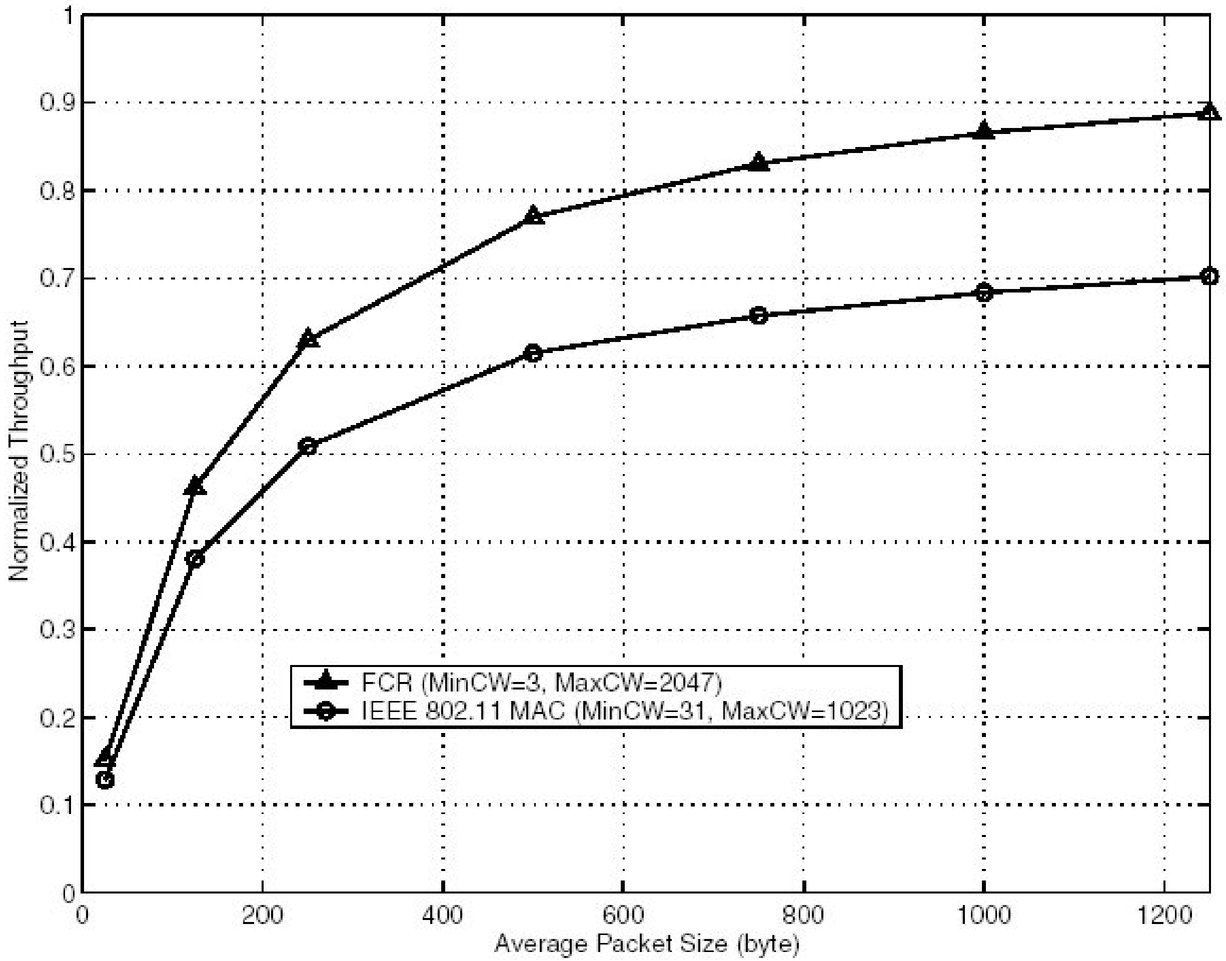
- When all stations do not have any packets to transmit, the virtual time is reset to zero
- Whenever a new station acquires the medium for packet transmissions, the maximum successive transmission limit can be determined by

$$T_{PkTrans,i} = g[v(t) - F_i^k]$$

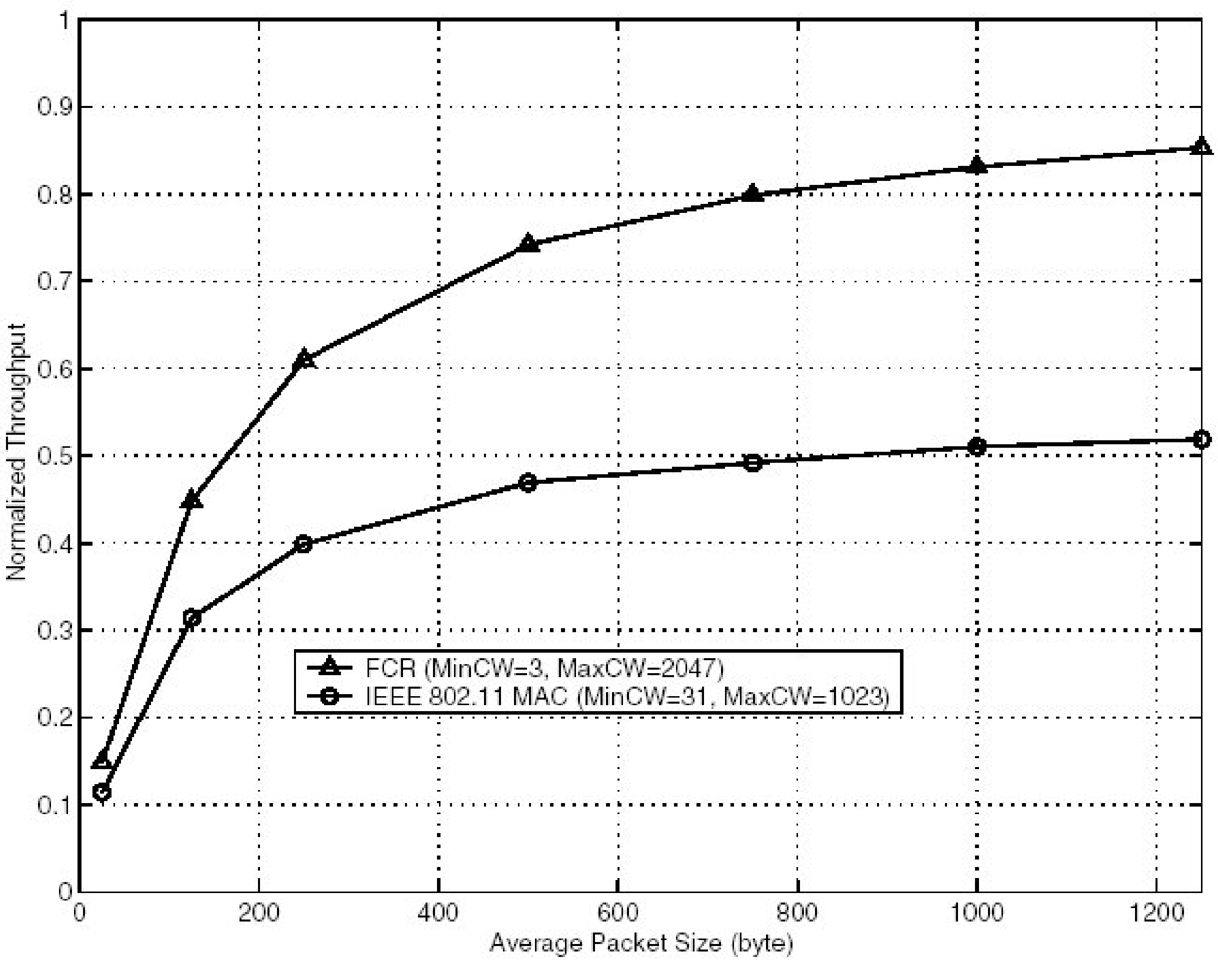
- If a station reaches its maximum successive transmission limit in its packet transmission period, the station will set its contention window size to the maximum value of *maxCW*

Performance Evaluation (FCR)

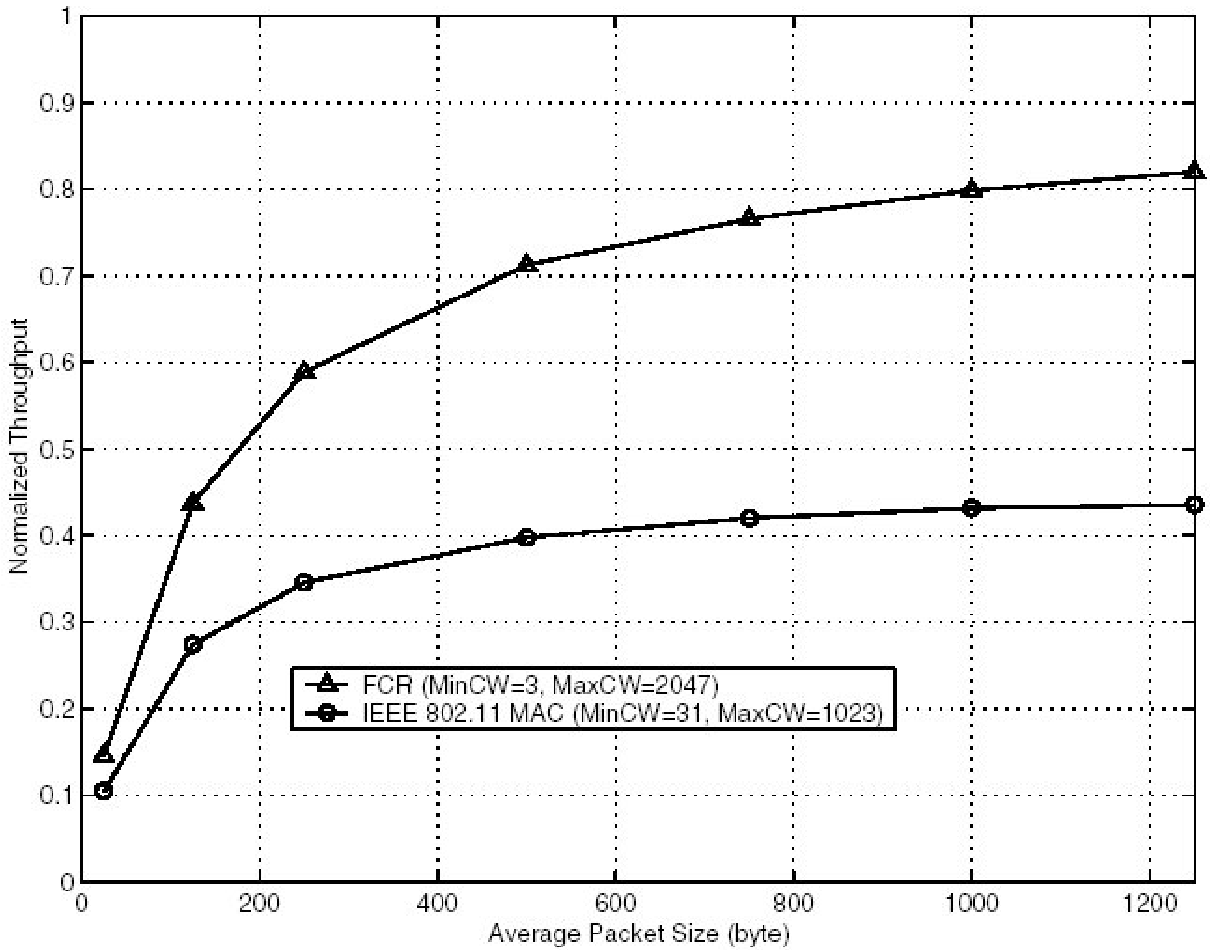
Throughput for 10 Stations WLAN



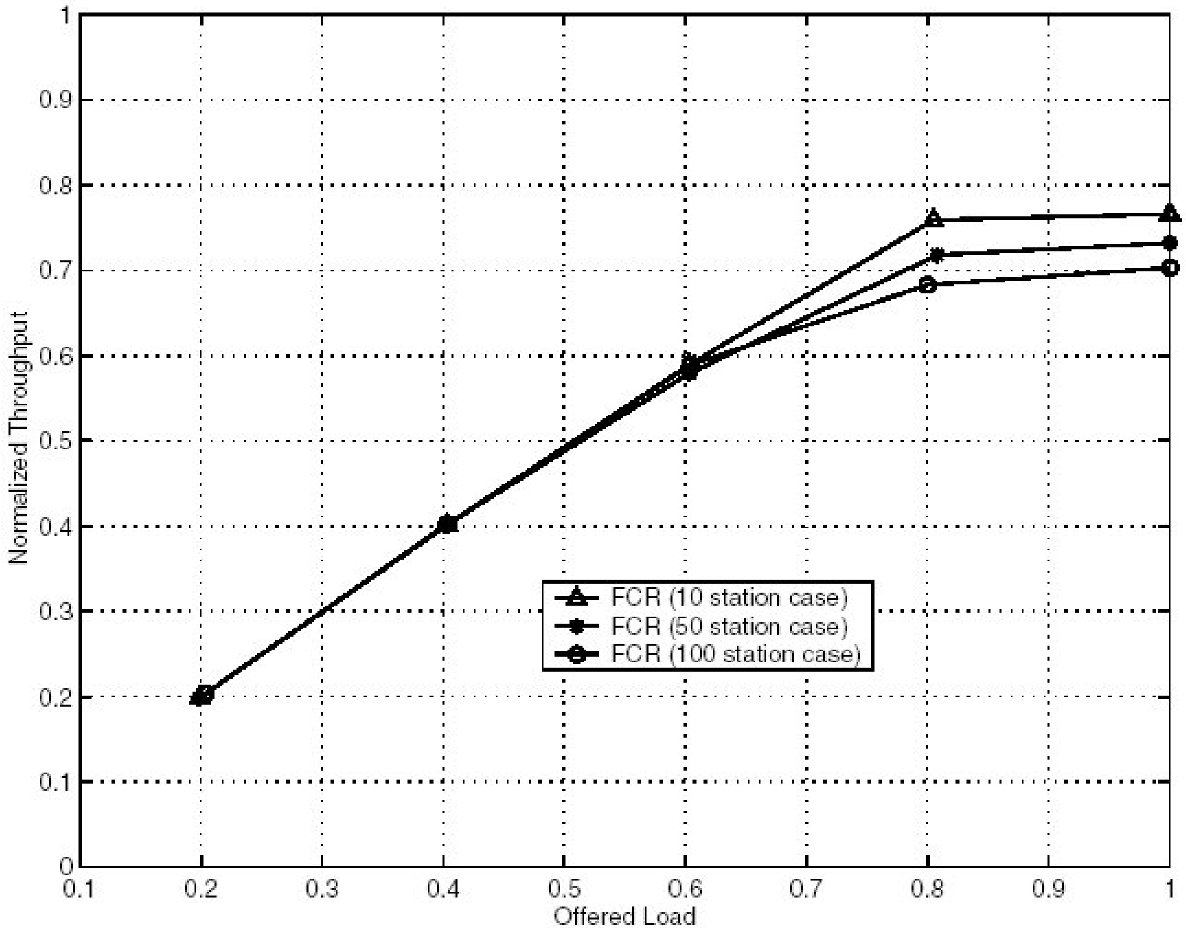
Throughput for 50 Stations WLAN



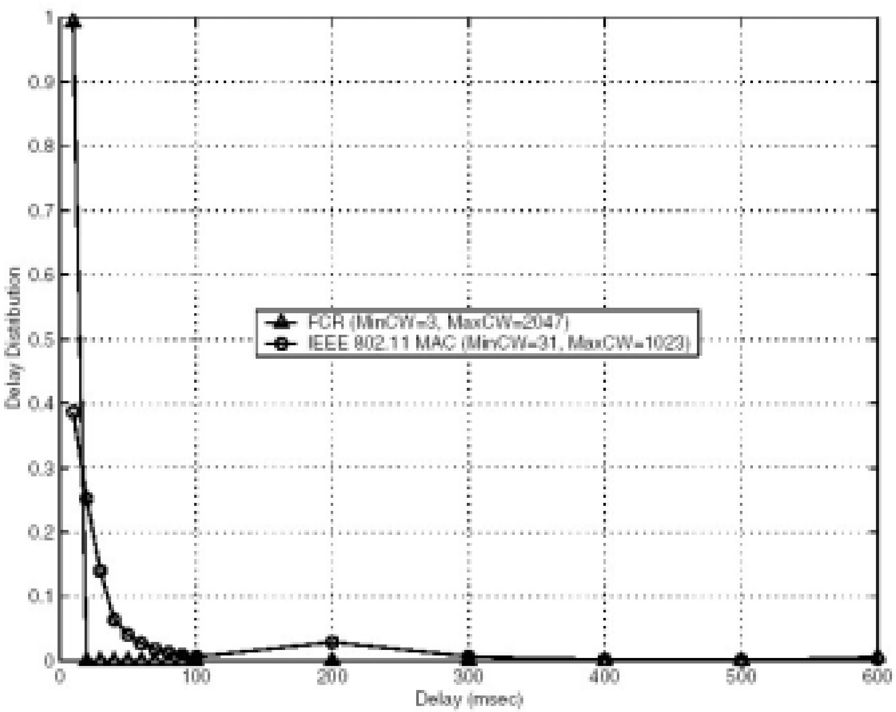
Throughput for 100 Stations WLAN



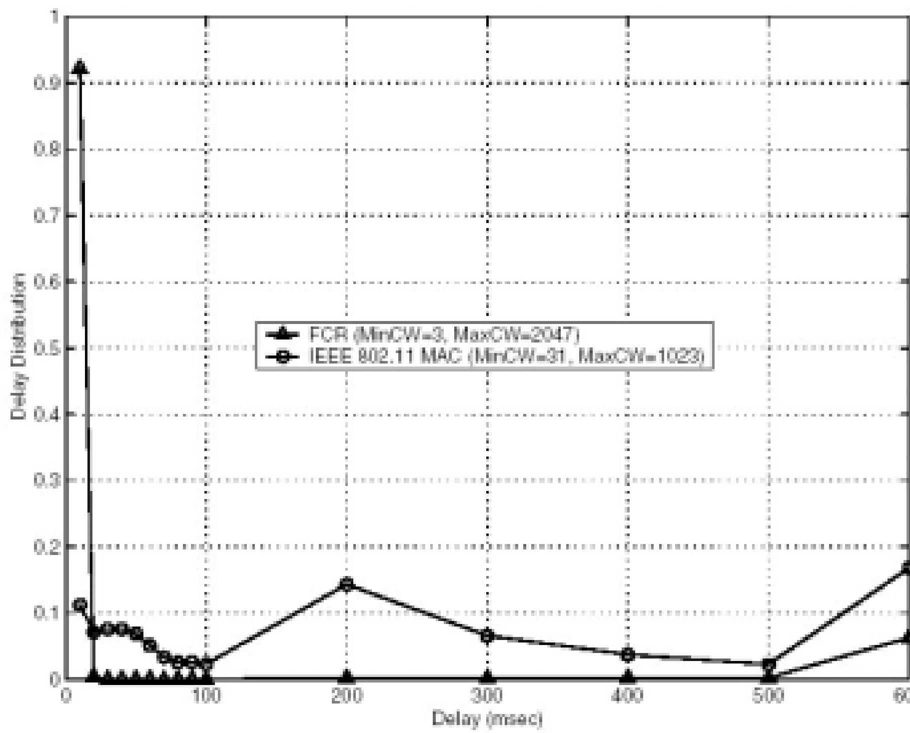
Throughput vs. Offered Load for FCR



Delay Distribution for WLAN

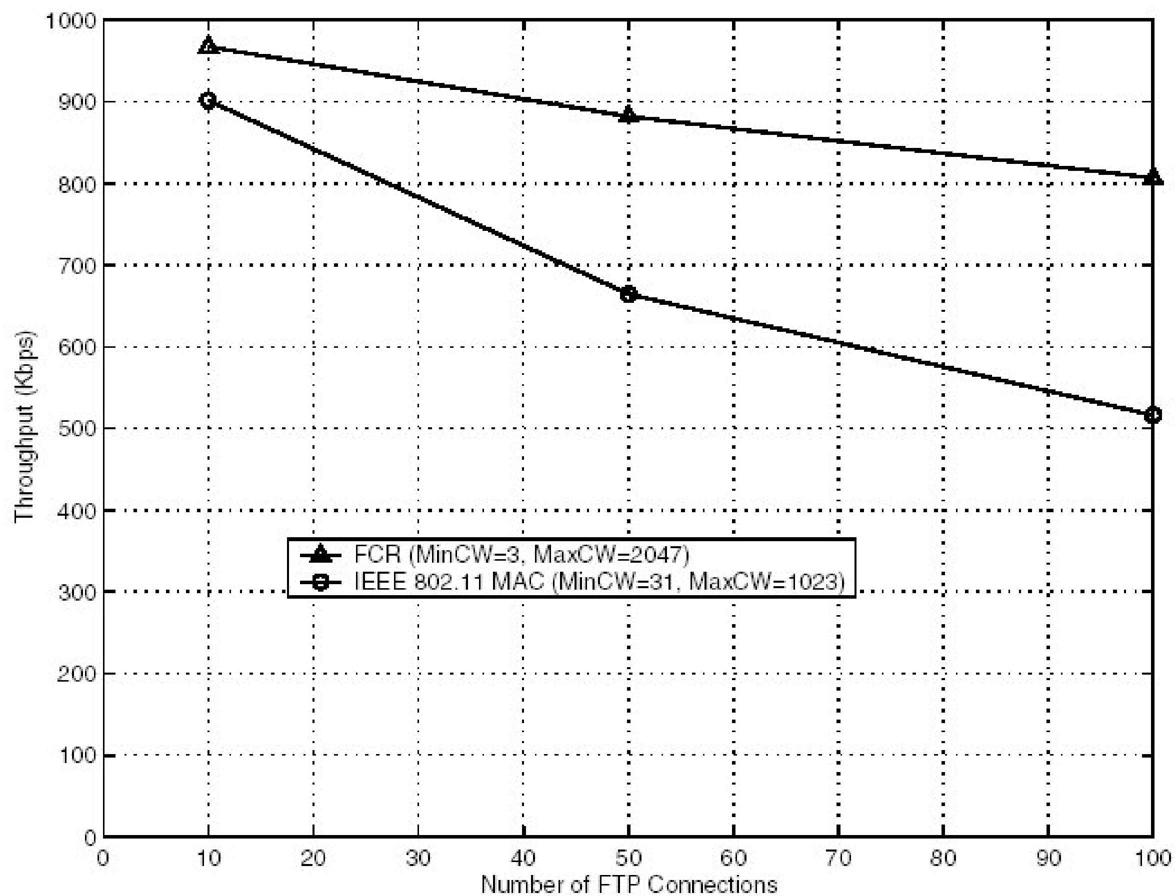


10 stations



100 stations

TCP Throughput for FCR algorithm for FTP traffic



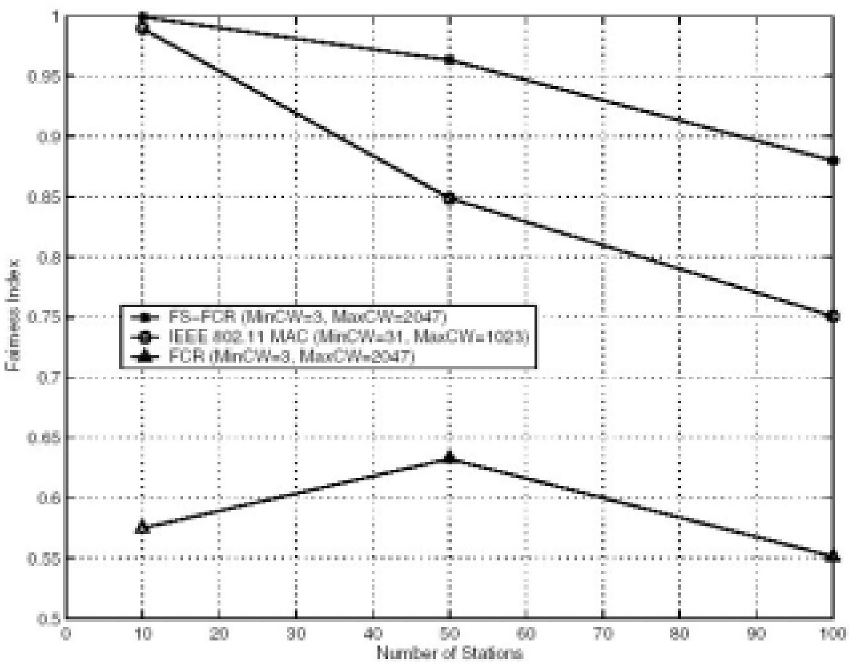
Performance Evaluation (FS-FCR)

Using Fairness Index

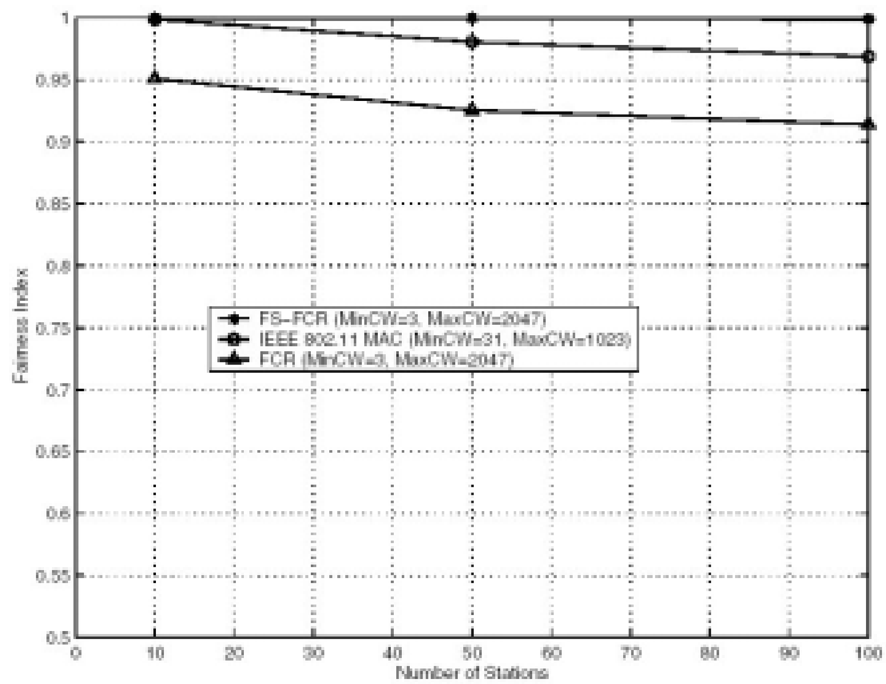
- Fairness index was defined in [19]
- n is the number of flows,
- T_i is the throughput of flow i
- Φ_i is the weight of the flow i
- The higher the fairness index, the better in terms of fairness

$$FairnessIndex = \frac{(\sum_i T_i/\phi_i)^2}{n \cdot \sum_i (T_i/\phi_i)^2}$$

Simulations of Fair Index

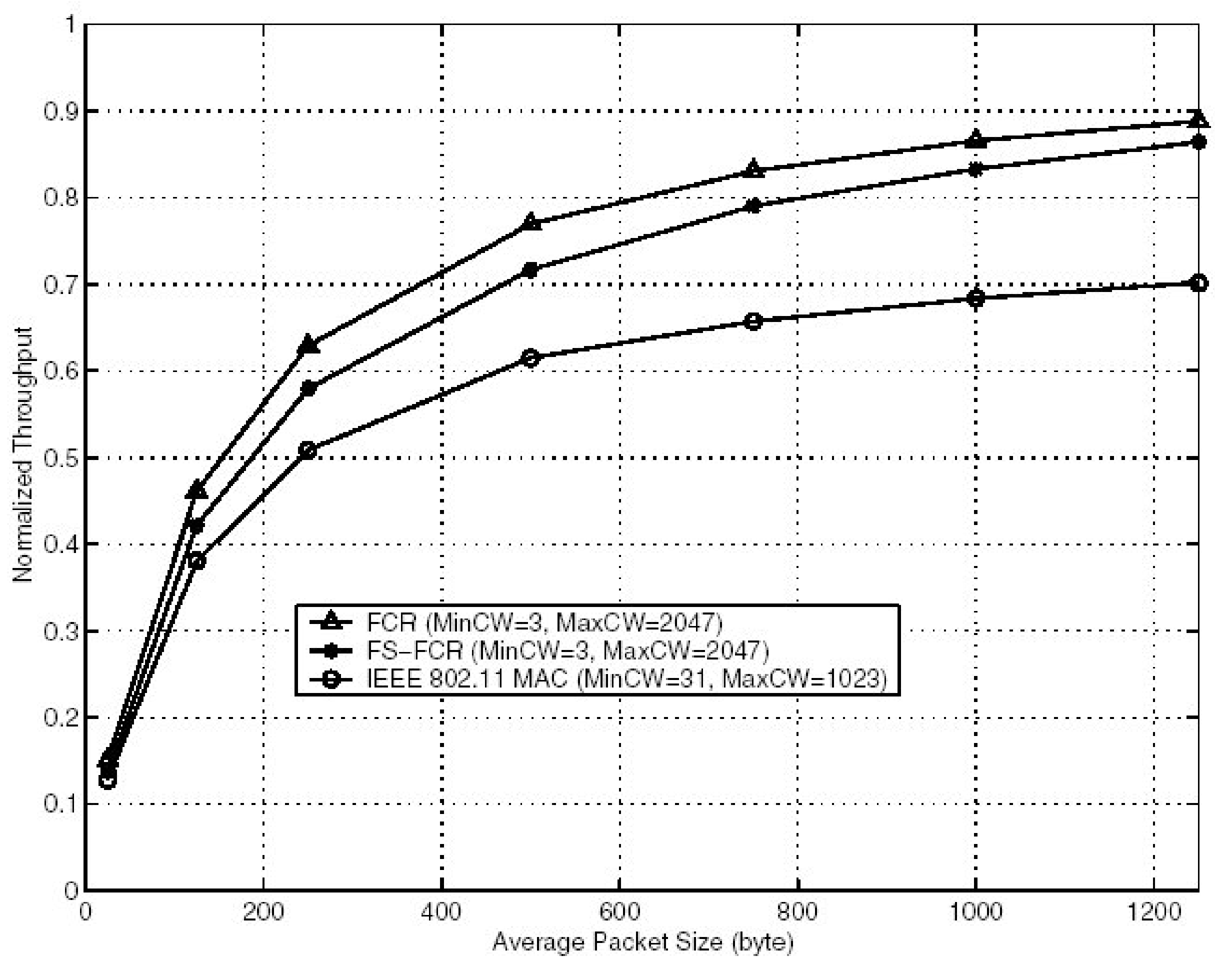


10 sec

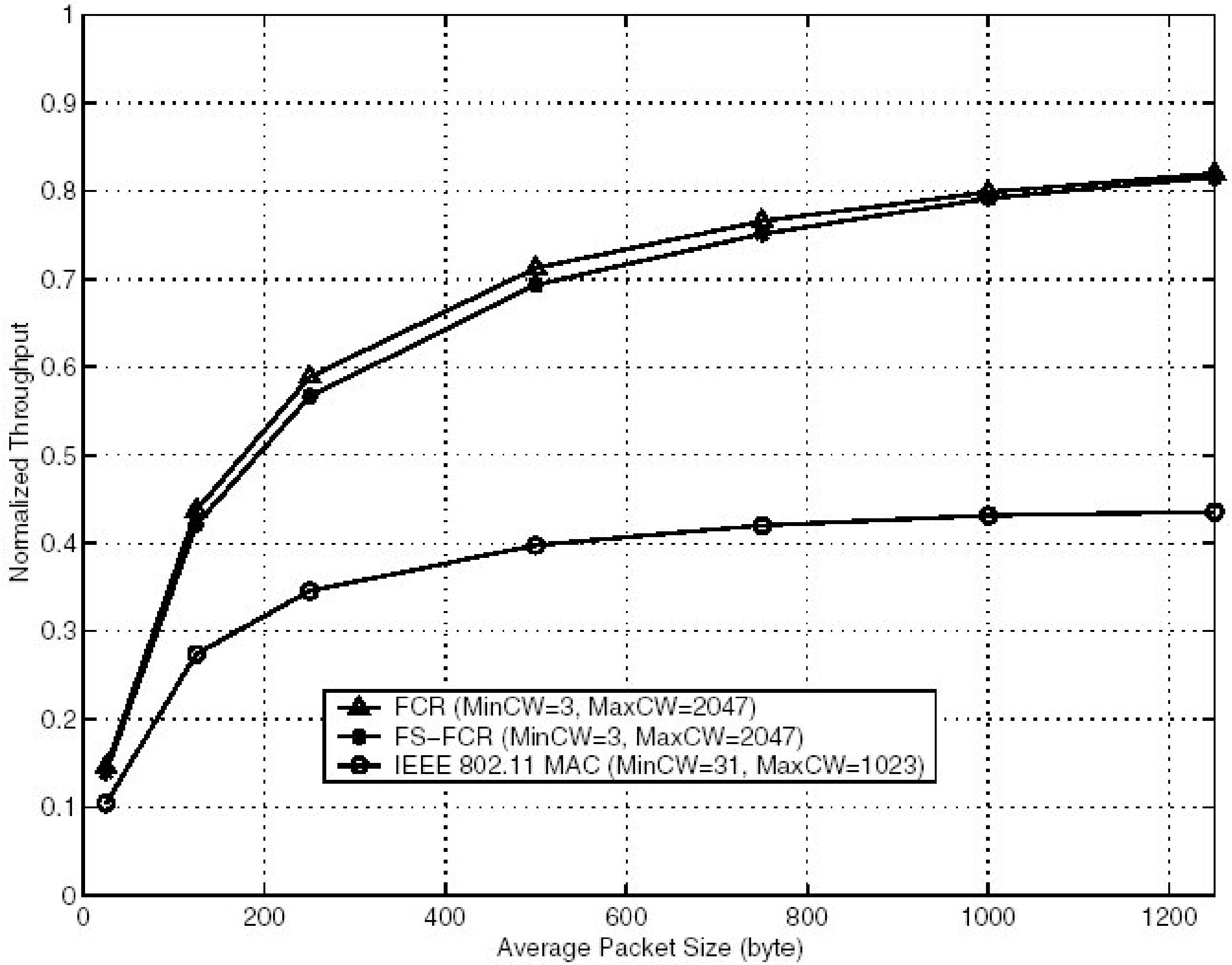


100 sec

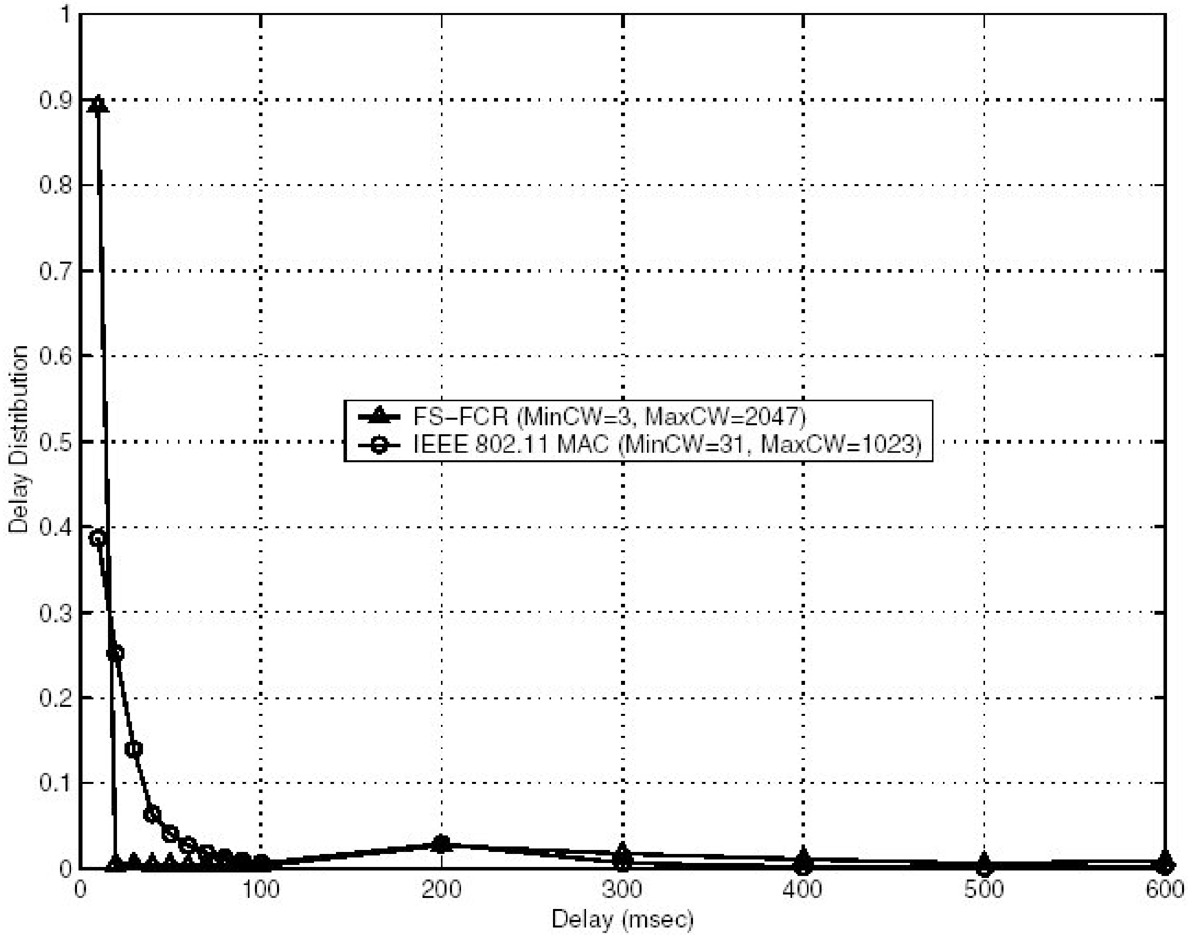
Throughput for 10 Stations WLAN



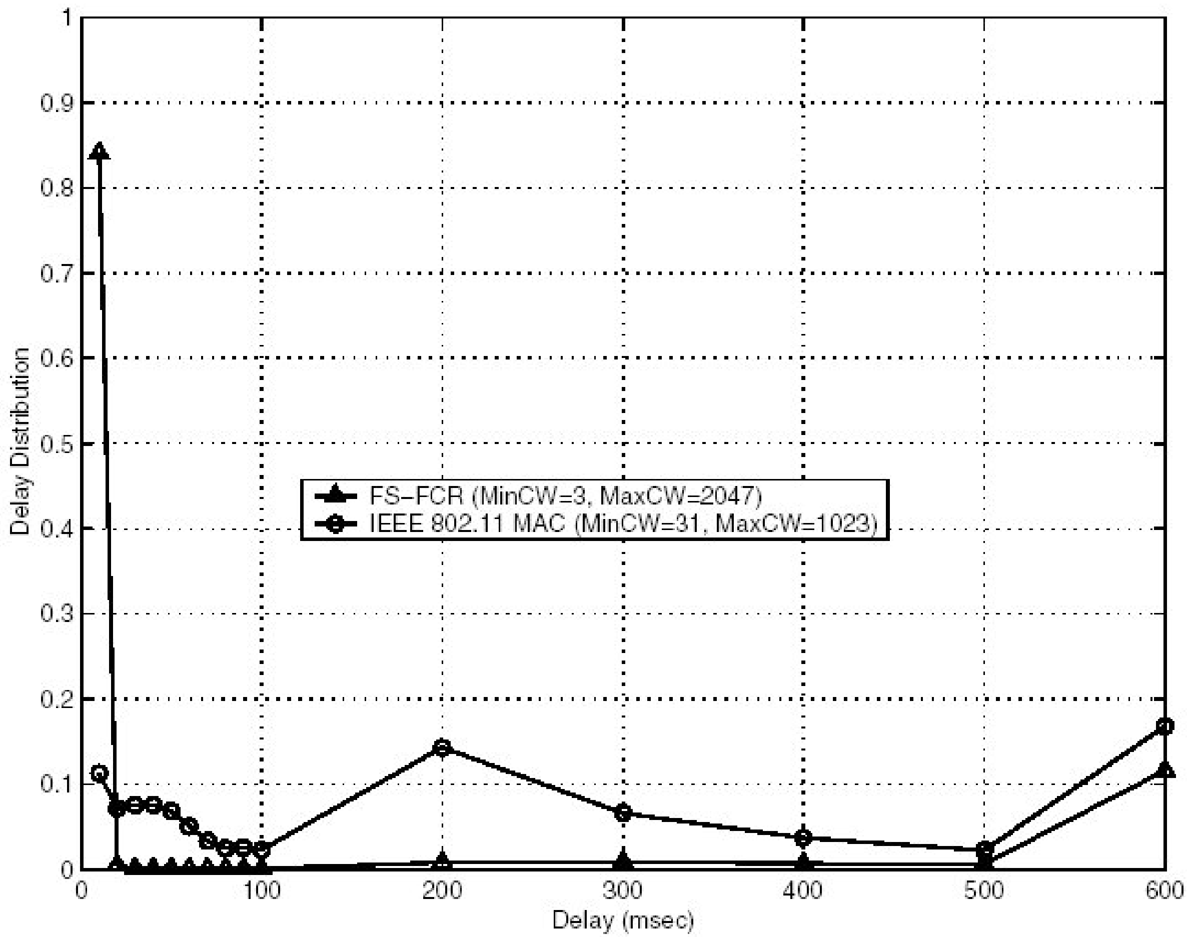
Throughput for 100 Stations WLAN



Delay Distribution for 10 Stations WLAN



Delay Distribution for 100 Stations WLAN



Discussion

- Can we use FCR or FS-FCR to maintain QoS requirement?
- If there are some stations do not use FS-FCR?

Conclusion

- FCR can achieve high throughput performance.
- Dynamically assign the successive transmission period in FCR can provide fairness.