Methods for restoring MAC Layer Fairness in 802.11 networks with Physical Layer Capture

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Contention based MAC: Collisions

- **Contention based MAC**
  - Listen before talk reduces the likelihood of simultaneous transmissions
- **Occurrence of Collisions**
  - Hidden terminals- senders hidden from each other collide at the receiver
  - Slot selection – senders may backoff for the same number of slots before attempting transmission

Handling Collisions

- **Simple models**
  - When two stations collide, both lose their frame
  - Both double their CW
  - Choose a random slot between (0, CW-1)
  - Count down until timer = 0
- **The reality in majority of 802.11 cards..**
  - Capture effect

Physical Layer Capture

- **General Definition**
  - In the event of a collision, the stronger frame is captured

- **Ns-2 definition**
  - In the event of a collision, the stronger frame is captured as long as it arrives first

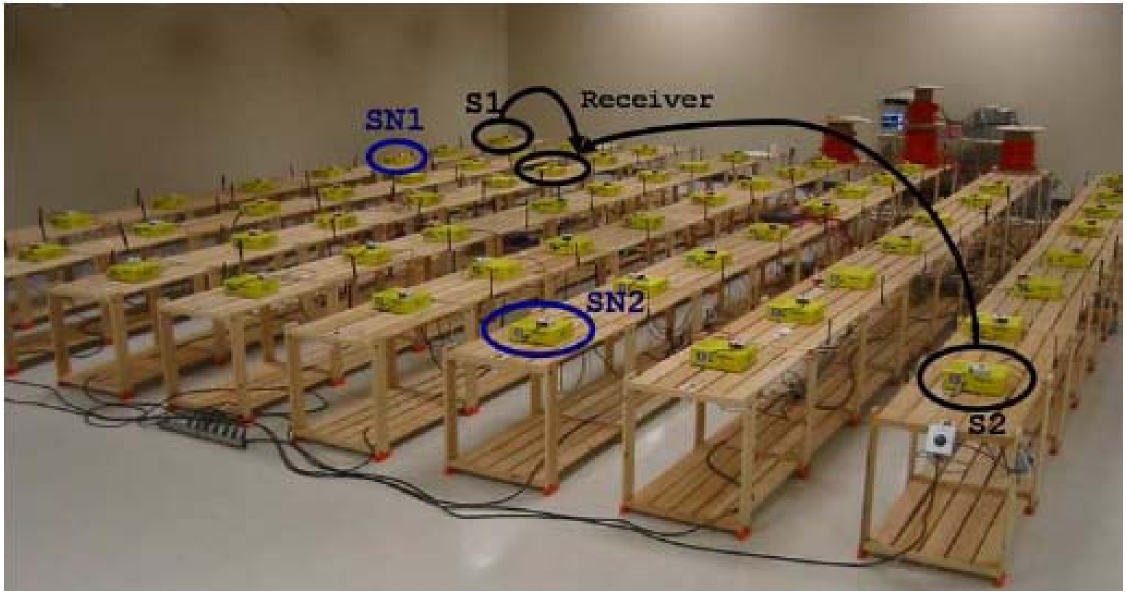
```
/*  If the power of the incoming packet is smaller than the
  *  power of the packet currently being received by at least
  *  the capture threshold, then we ignore the new packet */

if(pktRx_->txinfo_.RxPr / p->txinfo_.RxPr >= p->txinfo_CPThresh)
          {
                capture(p);
           } else {
                collision(p);
           }
```

- **Experimental observation**
  - In the event of a collision, the stronger frame is captured irrespective of the order or arrival (as long as it arrives before SFD of the first frame)* (~128 µseconds)

* Also reported previously by Kochut et.al in “Sniffing out the correct Physical Layer Capture model in 802.11b”, (ICNP’04)

Detecting capture effect

- **Method**
  - Construct a global timeline of packet exchanges using sender and receiver side sniffers
    - Sniffers are synchronized to the same AP of the actual senders
    - Sniffers use special “raw capture” mode to capture packets while remaining synchronized with AP
- **Setup**



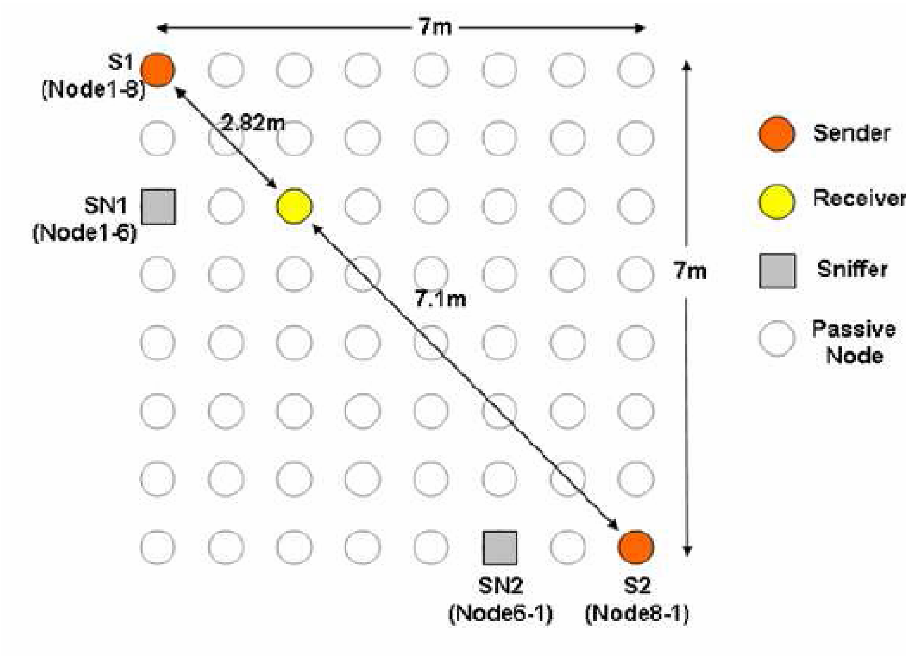
Constructing global timeline

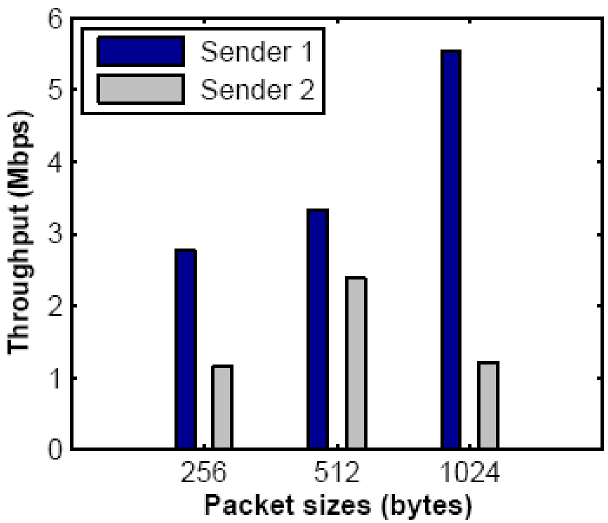
Time	Frame Type	Frame Size	Source IP Address	Destination IP Address	Seq. No.
737856416	Data	1088	192.168.1.8	192.168.3.6	476
737856532	Ack	14		192.168.8.1	
737857611	Data	1088	192.168.8.1	192.168.3.6	726
737857612	Data	1088	192.168.1.8	192.168.3.6	477
737857729	Ack	14		192.168.1.8	
737858633	Data	1088	192.168.1.8	192.168.3.6	478
737858749	Ack	14		192.168.1.8	

Two data frames seen at the sniffer, 1 μsec apart

ACK sent out by receiver to S1

Effect of capture on throughput fairness



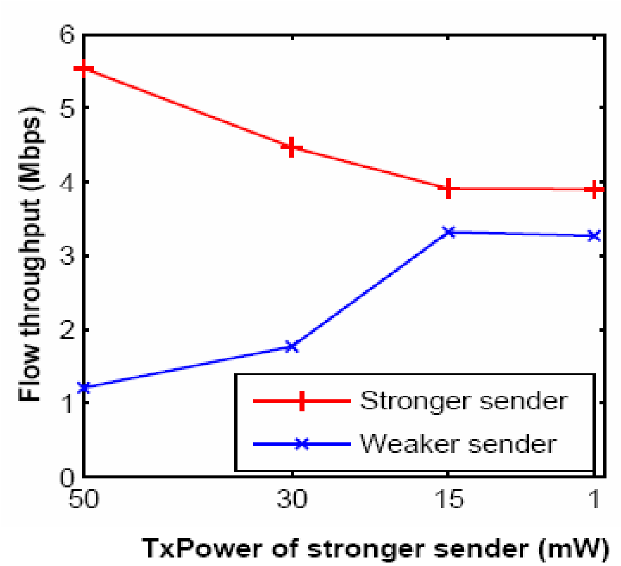


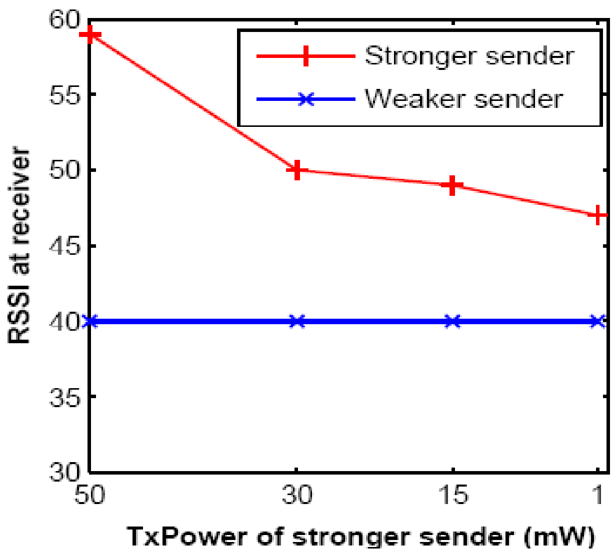
- Backoffs at weaker sender due to collisions
  - Throughput unfairness

Restoring fairness

- PHY parameters
  - Transmit power control
- MAC parameters
  - Adjusting number of retransmissions at weaker sender
  - Adjusting CWMin
  - Adjusting TxOp
  - Adjusting AIFS

Transmit power control

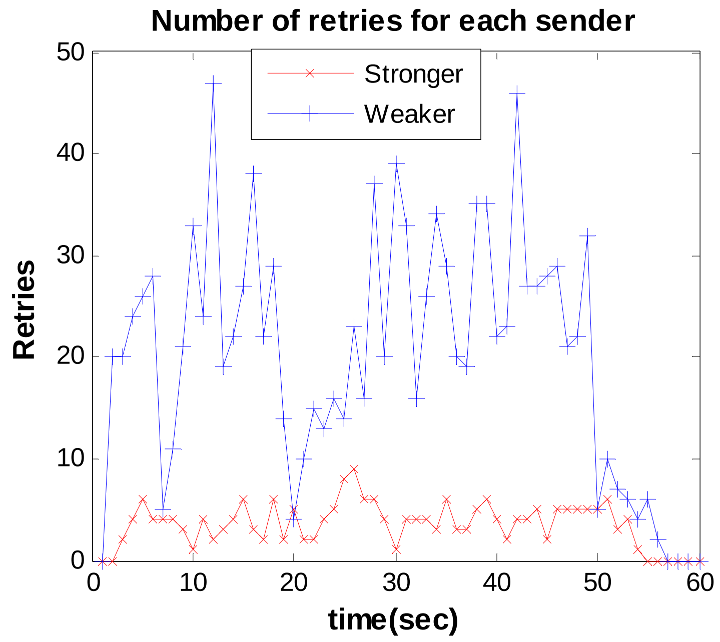


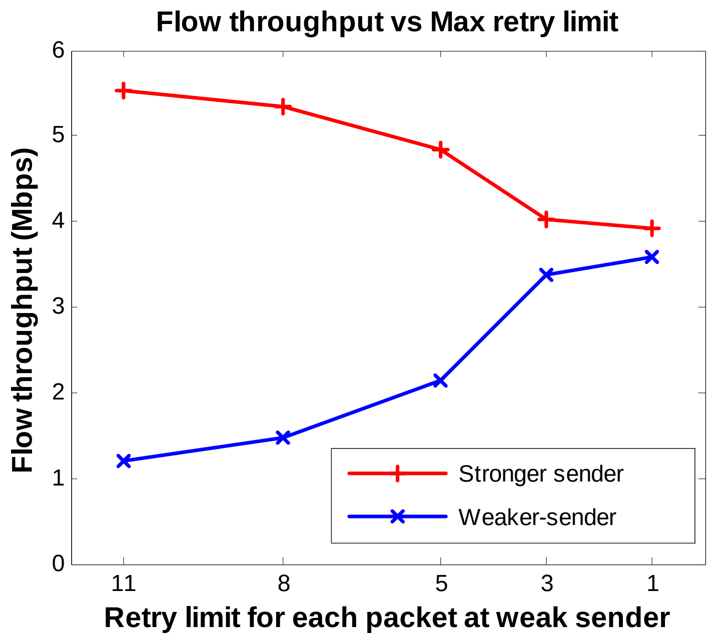


- Limited dynamic range of TxPower control* (~0-20 dBm)
- Limited granularity (~1 dB)

*Some exceptions: Intel IPW 2200 cards allow txpower setting of -12dBm

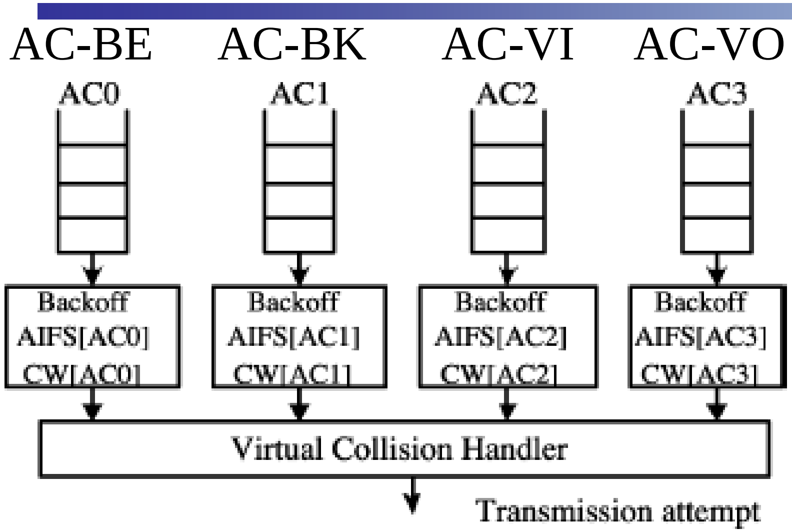
Adjusting no. of retries at weaker sender





- Reduce the amount of time spent in backoff and increase the number of transmission opportunities
- TCP traffic: may be a problem due to timeouts at transport layer

EDCF parameters - Summary

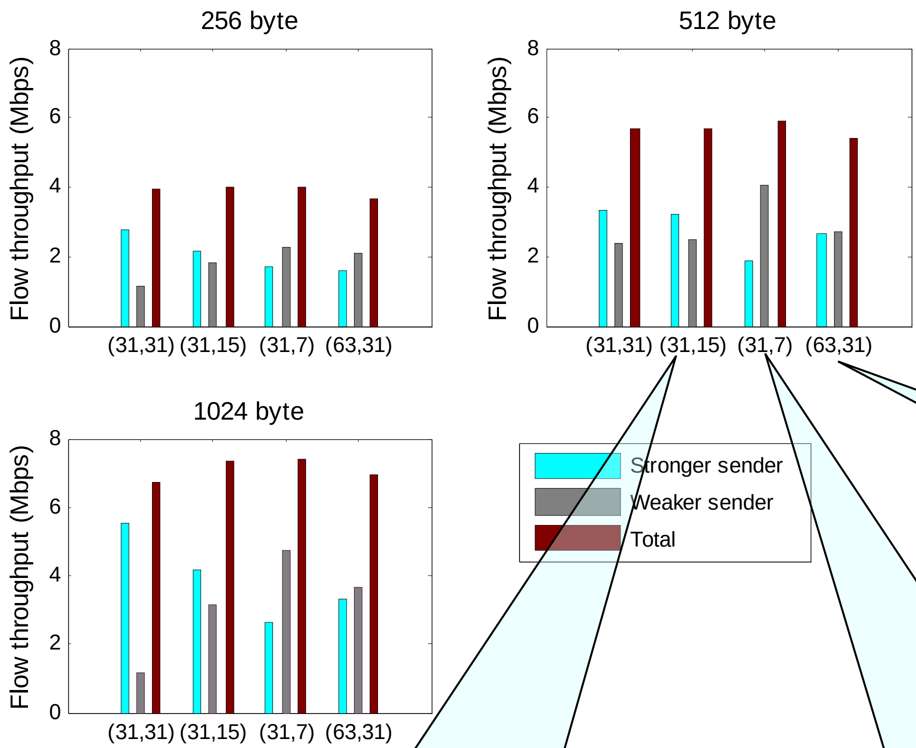


AC	AC_BE	AC_BK	AC_VI	AC_VO
AIFSN	7	3	2	2
CWMin	15	15	7	3
CWMax	1023	1023	31	15
TxOpLimit	0	0	~6ms	~3ms

- 4 Access Categories (AC's)
- Contention Window Parameters per AC
- AIFS (Arbitration Inter-frame Space) per AC
- TxOp (Transmission Opportunity) per AC

Prioritized access based on a combination of CW, AIFS, TxOP settings for each AC.

Adjusting CWmin



Approach

- Reduce CWMin for weaker sender (31, 7), (31, 15)
- Increase CWMin for stronger sender (63, 31)

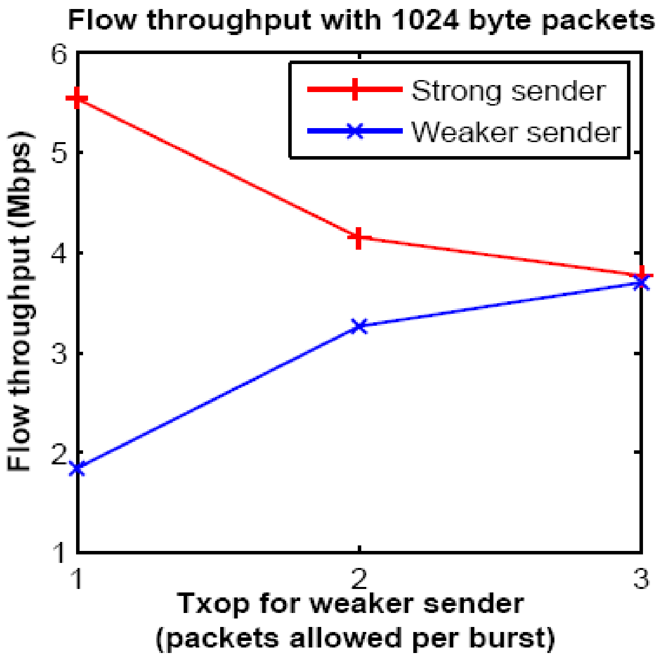
Undercorrected: stronger sender still gets higher throughput

Overcorrected: weaker sender gets higher throughput

Good throughput balance, however lower channel utilization and hence lower total throughput

Limited granularity (CWmin settings allowed only in powers of two)

Adjusting TxOp for weaker sender

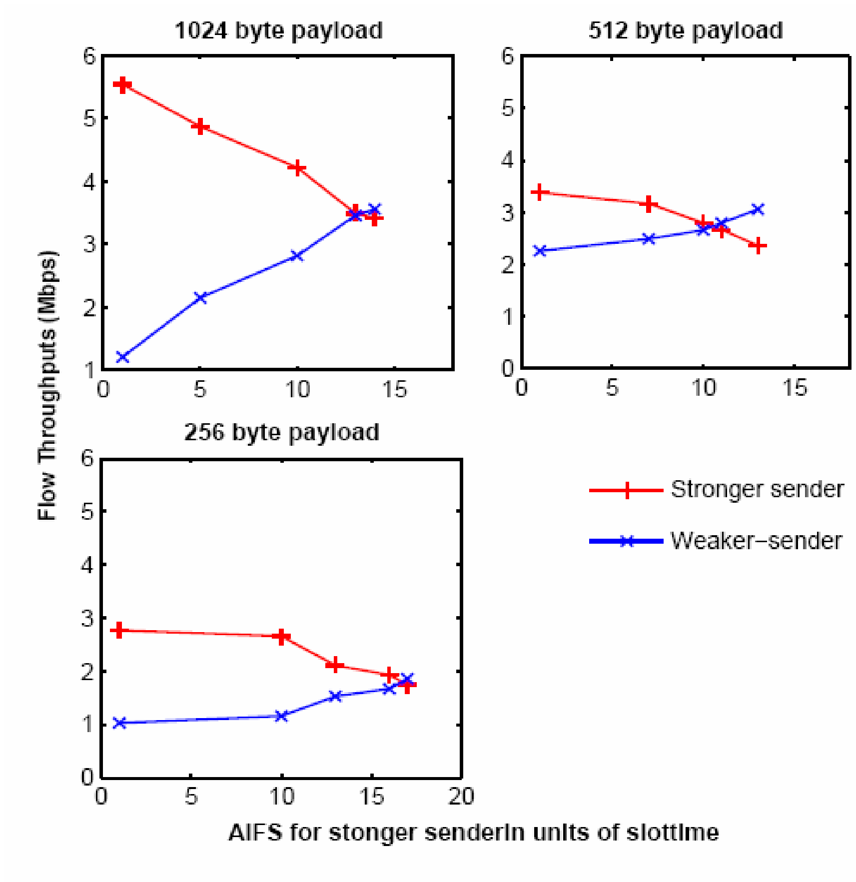


Approach

- Adjust TxOp of weaker sender to balance the channel occupancy of each flow
- This will give the weaker sender more opportunity for its data transmission

- Allows a fine grained control

Adjusting AIFS for stronger sender



AIFS [AC] = SIFS + AIFSn[AC]*slotTime

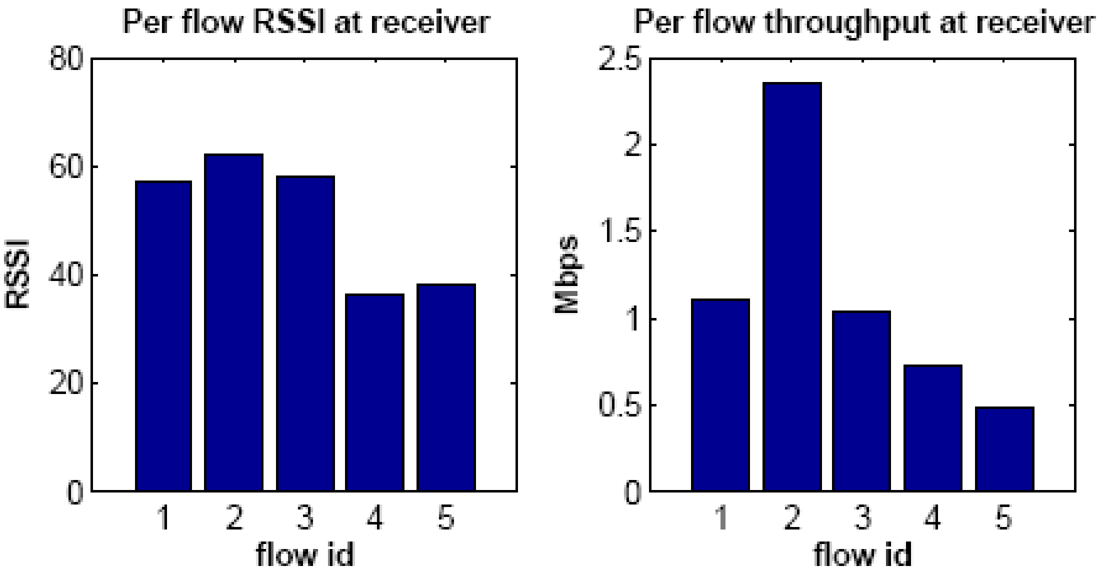
e.g, for 802.11b, AIFSn = 2 and

AIFS = DIFS = SIFS + 2*slottime

Summary of results

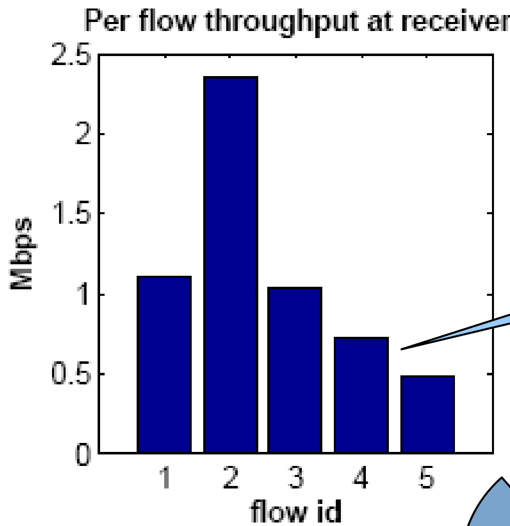
Method	Throughput (Strong sender, Mbps)	Throughput (Weaker sender, Mbps)
No adaptation	5.54	1.21
TxPower control	3.9	3.27
Retries	3.93	3.58
CWMin	3.31	3.64
TxOp	3.77	3.7
AIFS	3.49	3.46

Joint Adaptation

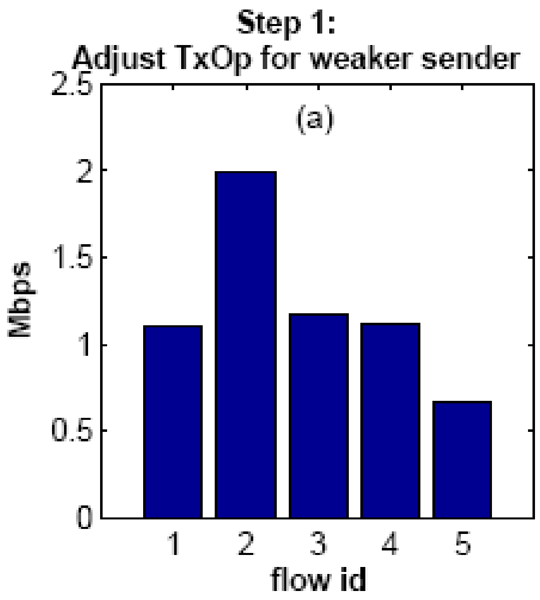


- 5 senders with different RSSI at the receiver
- Unequal throughput distribution
- Goal- To restore fairness

Heuristic Approach: Step 1

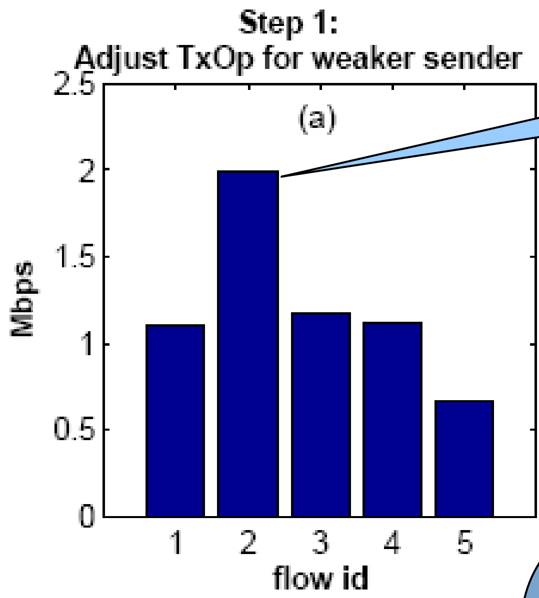


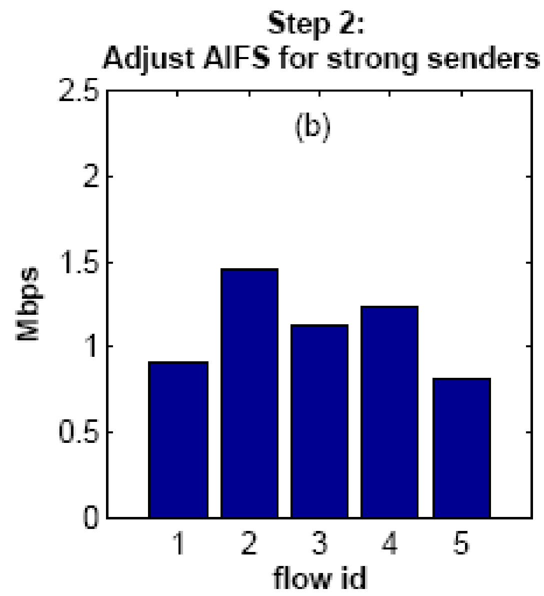
Step1: Increase TxOp for flows 4 and 5
TxOp = 2 packets for flow 4
TxOp =3 packets for flow 5



Heuristic Approach : Step 2

Step2: Suppress flow 2
Increase AIFS of flow 2





Conclusions and Future Work

- Centralized and distributed algorithms that utilize TXOP and AIFS to restore fairness and provide QoS guarantees
- Performance evaluation in environments with non-compliant senders.
  - Legacy 802.11 clients with no .11e support
  - Misbehaving clients
- More experiments on a bigger grid…