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Network Technologies and Strategies

Fairness in Collision-Free WLANs

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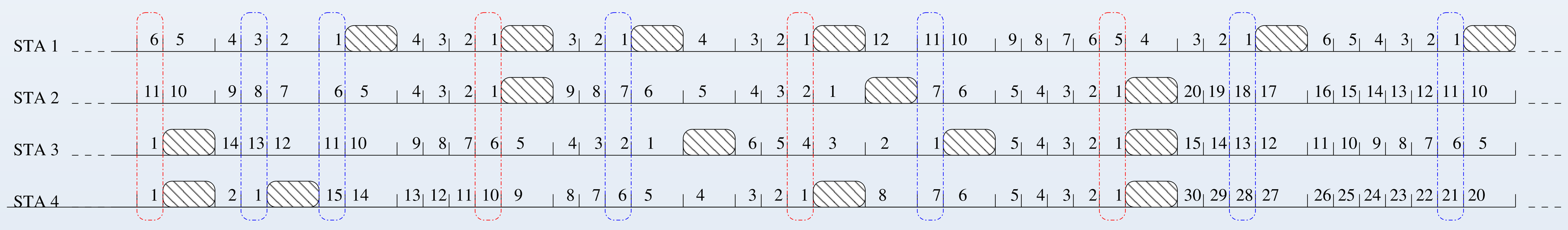
Motivation

Wireless networks are composed of nodes that must contend for the medium in a distributed manner. If two or more contenders attempt transmission at the same time, a collision occurs.
Collisions are the main cause of throughput degradation in wireless local area networks (WLANs), so by constructing collision-free WLANs one can attain greater levels of throughput.

CSMA/CA

Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) is the most widely used protocol for medium access control (MAC) in WLANs. CSMA/CA's job is to coordinate access to the medium for each contender.

Time in WLANs is slotted, so CSMA/CA divides it into empty, collision and successful transmission time slots. When a node has something to transmit, it picks a random backoff counter $B \in [0, CW(k) - 1]$, where $k \in [0, \dots, m]$ is the *backoff stage* and $CW(k) = 2^k CW_{\min}$ is the contention window, with $CW_{\min}$ its minimum value. Each passing empty slot decrements B by one. Contenders attempt transmission when the counter expires ($B = 0$).



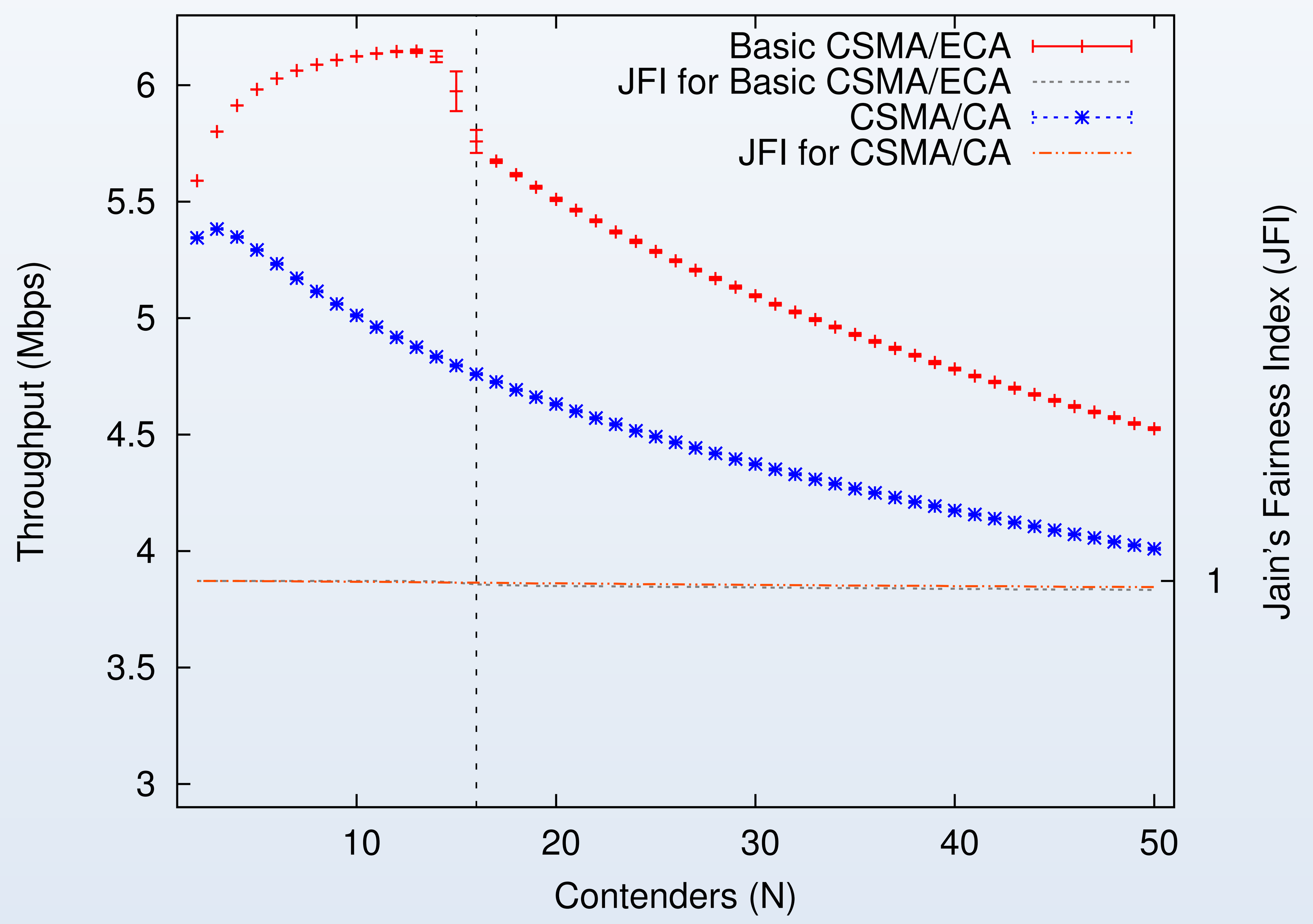
Example CSMA/CA behavior ($CW_{\min} = 16$).

If a contender collides, it doubles the range of possible values whence it draws B by incrementing the backoff stage (k) in one. This measure effectively reduces the collision probability. After a successful transmission, the contender resets is backoff stage ($k = 0$).

Basic ECA

CSMA/CA relies in a random backoff counter (B) which by its nature generates collisions. Furthermore, CSMA/CA instructs nodes to reset the backoff stage (k) after a successful transmission: increasing the collision probability. Carrier Sense Multiple Access with Enhanced Collision Avoidance [1] (Basic CSMA/ECA) achieves a collision-free state by picking a deterministic backoff counter $B_d = CW_{\min}/2$ after successful transmissions. This choice makes it possible for Basic CSMA/ECA to fairly coexist with CSMA/CA.

This choice of B_d after successful transmissions results in a collision-free state, causing Basic CSMA/ECA's throughput to go over CSMA/CA's.



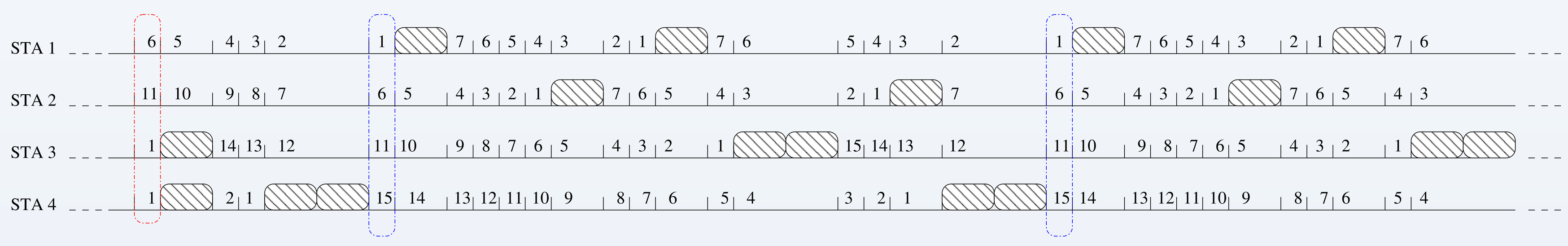
Throughput and fairness in CSMA/CA and Basic CSMA/ECA ($CW_{\min} = 32$).

Nevertheless, when the number of contenders surpasses $CW_{\min}/2$, the system incurs in a mixed behavior; some nodes pick a random and others a deterministic backoff counter. This setup has undesired repercussions in the attained throughput, approximating Basic CSMA/ECA's to CSMA/CA's.

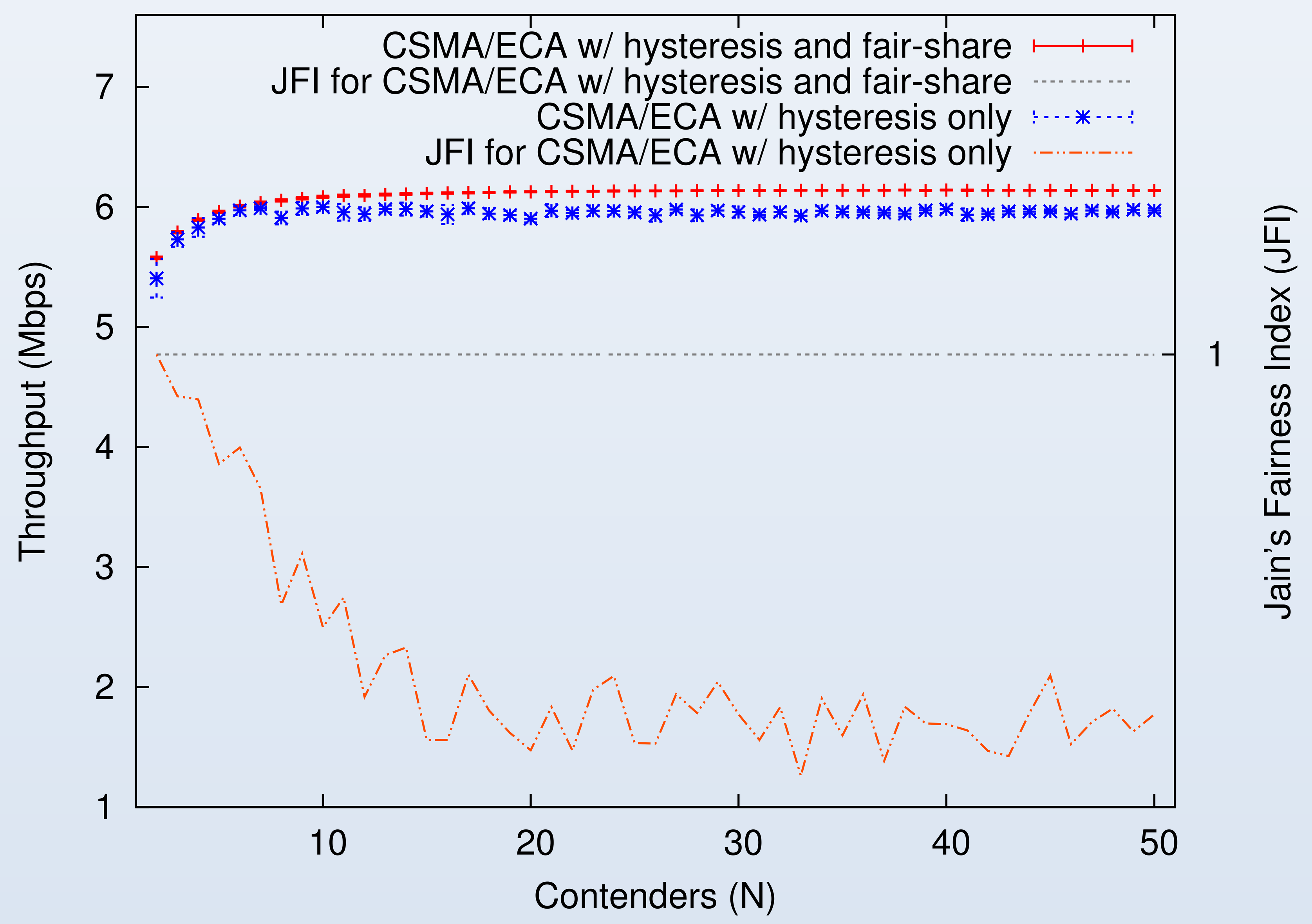
CSMA/ECA + hysteresis and fair share

CSMA/ECA is totally distributed, that means that the number of nodes is unknown to all contenders. So, to make it possible to achieve a collision-free state with more than $CW\min/2$ contenders, CSMA/ECA instructs nodes **not** to reset their backoff stage after successful transmissions and to pick a new deterministic backoff $B_d = CW(k)/2$. We called this measure *hysteresis* and it produces backoffs larger than $CW_{\min}/2$, thus making it possible to allocate more contenders in a collision-free fashion.

Introducing hysteresis produces an uneven distribution of system's available throughput (given that some nodes may have larger B_d than others). This unfairness issue is averted by allowing nodes at backoff stage k to send 2^k packets at each transmission attempt. This is called *fair share* [2].



Example CSMA/ECA behavior with hysteresis and fair share ($CW_{\min} = 16$).



Throughput and fairness when incorporating hysteresis and fair share to CSMA/ECA.

Conclusions and Future plans

Hysteresis allows CSMA/ECA to allocate any number of contenders in a collision-free state, while fair share compensates the unfairness issue; allowing CSMA/ECA to attain greater throughput than CSMA/CA under most typical conditions.
As future work, we plan to:

- Test CSMA/ECA under non-saturated scenarios.
- Implement IEEE 802.11e EDCA quality of service measures.
- Implement CSMA/ECA in cheap commodity hardware [3].

References

[1] Barcelo, J. and Toledo, A.L. and Cano, C. and Oliver, M. Fairness and Convergence of CSMA with Enhanced Collision Avoidance (ECA). *2010 IEEE International Conference on Communications (ICC)* , may 2010, pp 1–6.

[2] Sanabria-Russo, L. and Barcelo, J. and Bellalta, B. Fairness in Collision-Free WLANs. *ArXiv e-prints* , February 2013.

[3] Tinnirello, I. and Bianchi, G. and Gallo, P. and Garlisi, D. and Giuliano, F. and Gringoli, F. Wireless MAC processors: Programming MAC protocols on commodity Hardware. *INFOCOM, 2012 Proceedings IEEE* , march 2012, pp 1269–1277.