Collision Aware Rate Adaptation (CARA)

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Outline

- Introduction to Dynamic Rate Adaptation
- Related Work
  - Classification
  - ARF
  - RBAR
- CARA-1 and CARA-2
- Simulation Results
- Conclusions and Future Work

Basic CSMA/CA

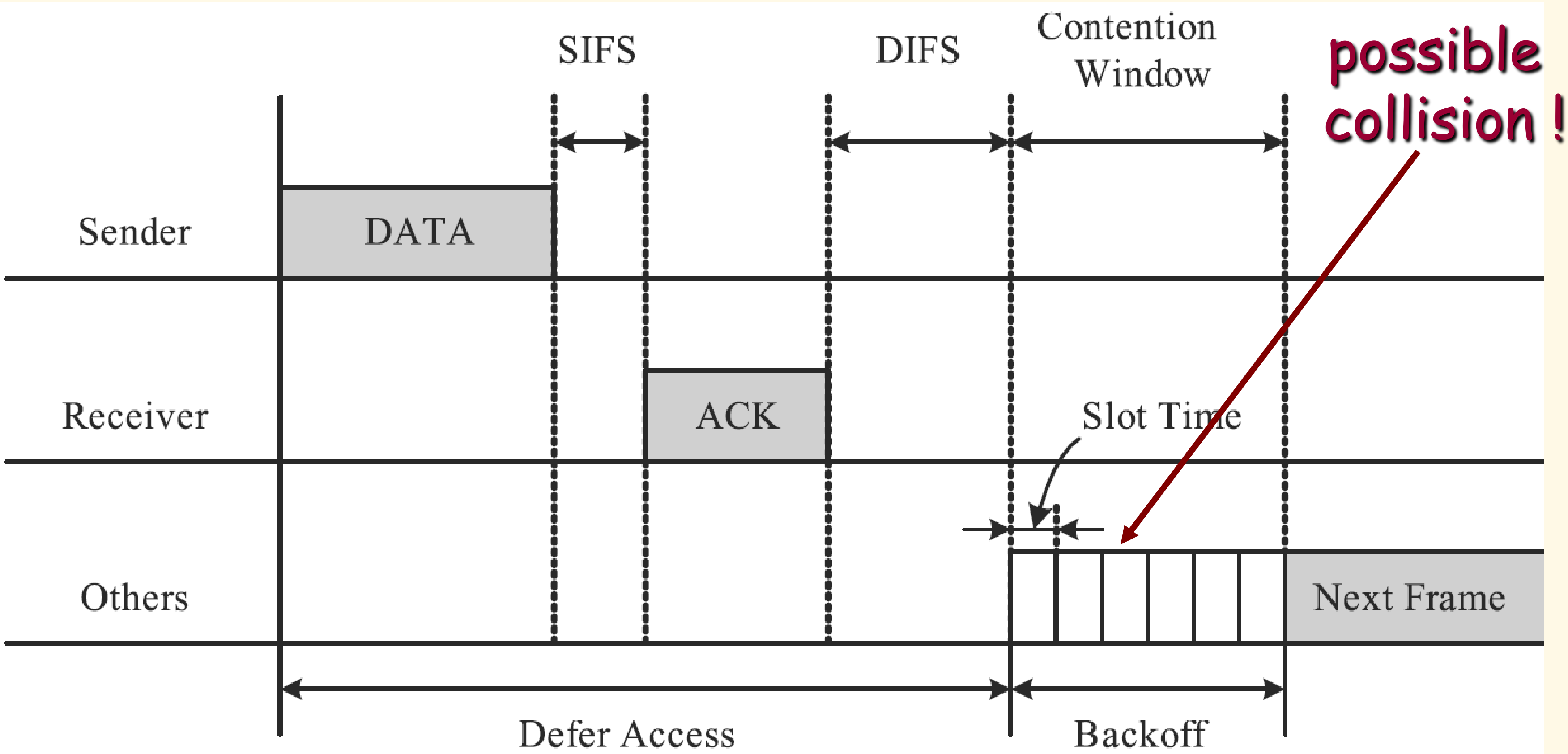


Fig. 1 CSMA/CA protocol of IEEE 802.11 MAC DCF. [N. Kim]

802.11 Physical Layer

'Adjust transmission rate on the fly'

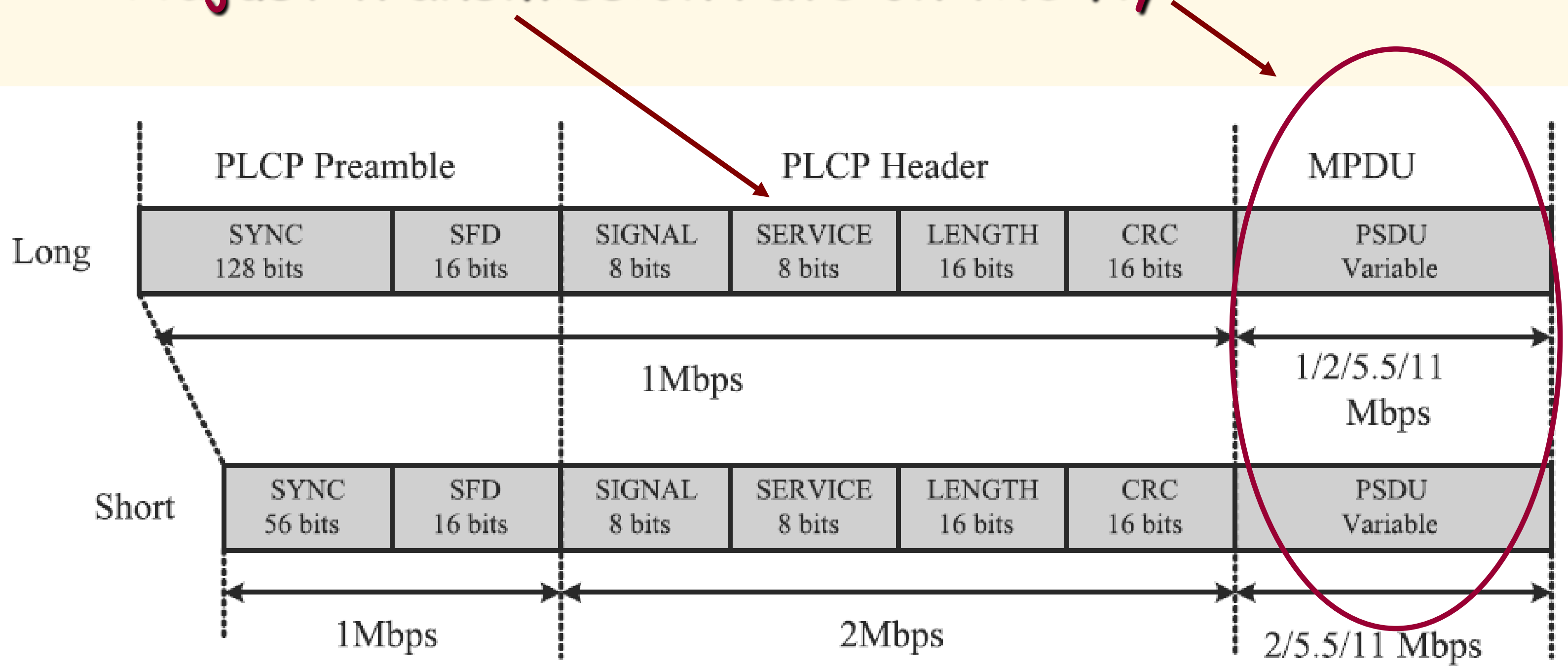


Fig. 2 IEEE 802.11b HR/DSSS PHY framing structure.

[N. Kim]

BER vs SNR

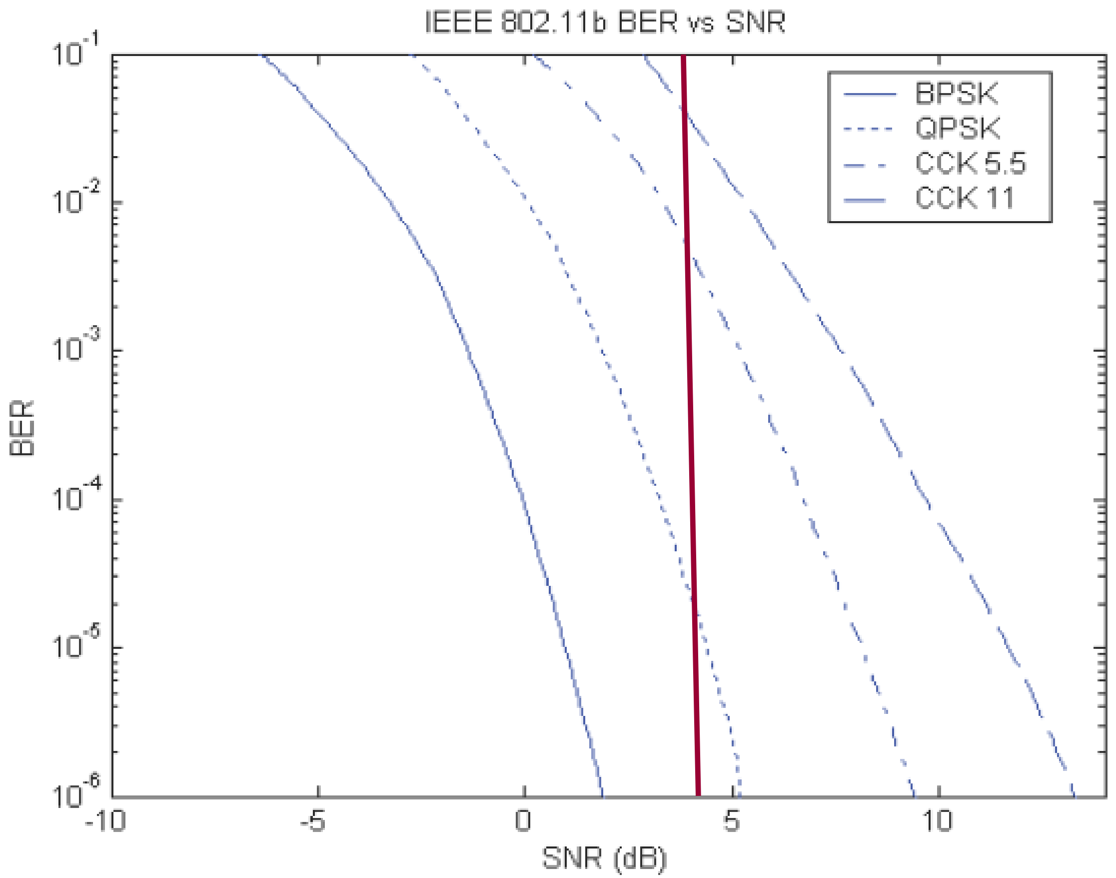


Figure 2. IEEE 802.11b BER vs. SNR

[Pavon]

Throughput vs SNR

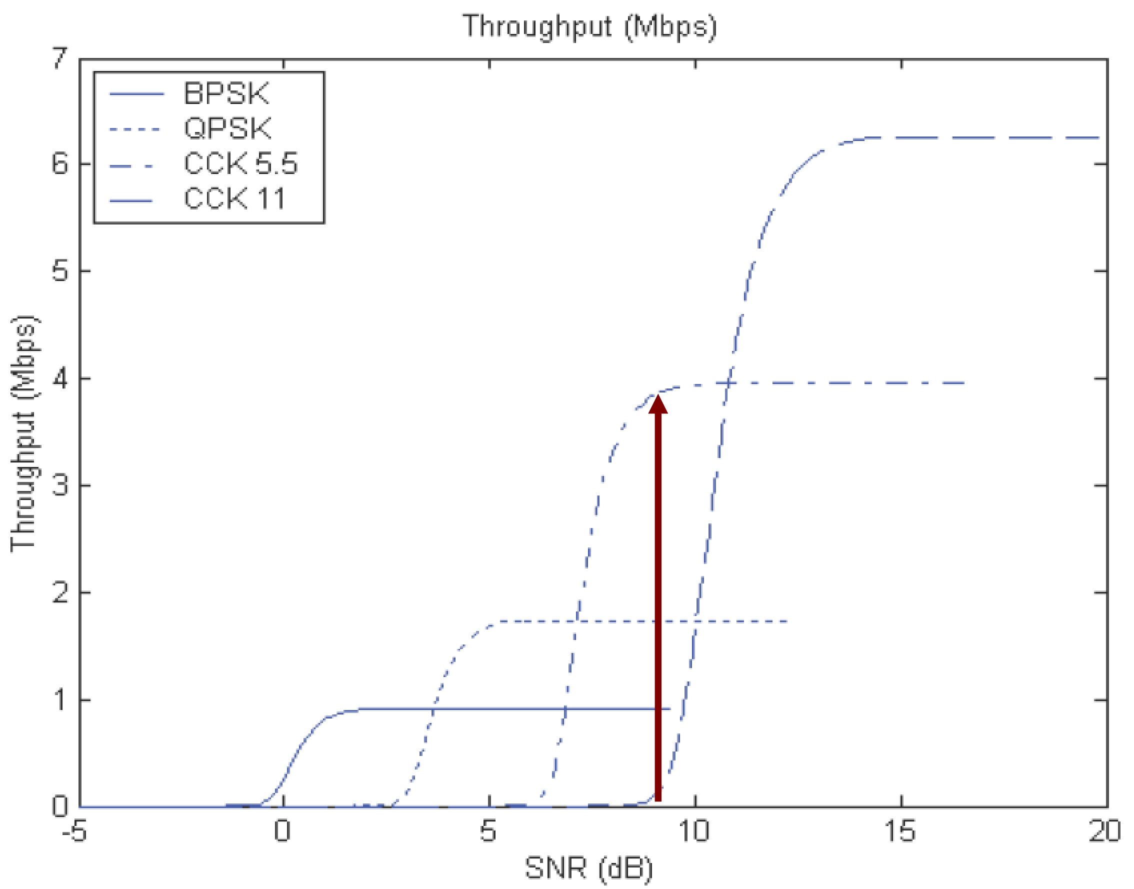


Figure 4. IEEE 802.11b throughput vs. SNR

[Pavon]

Unfairness

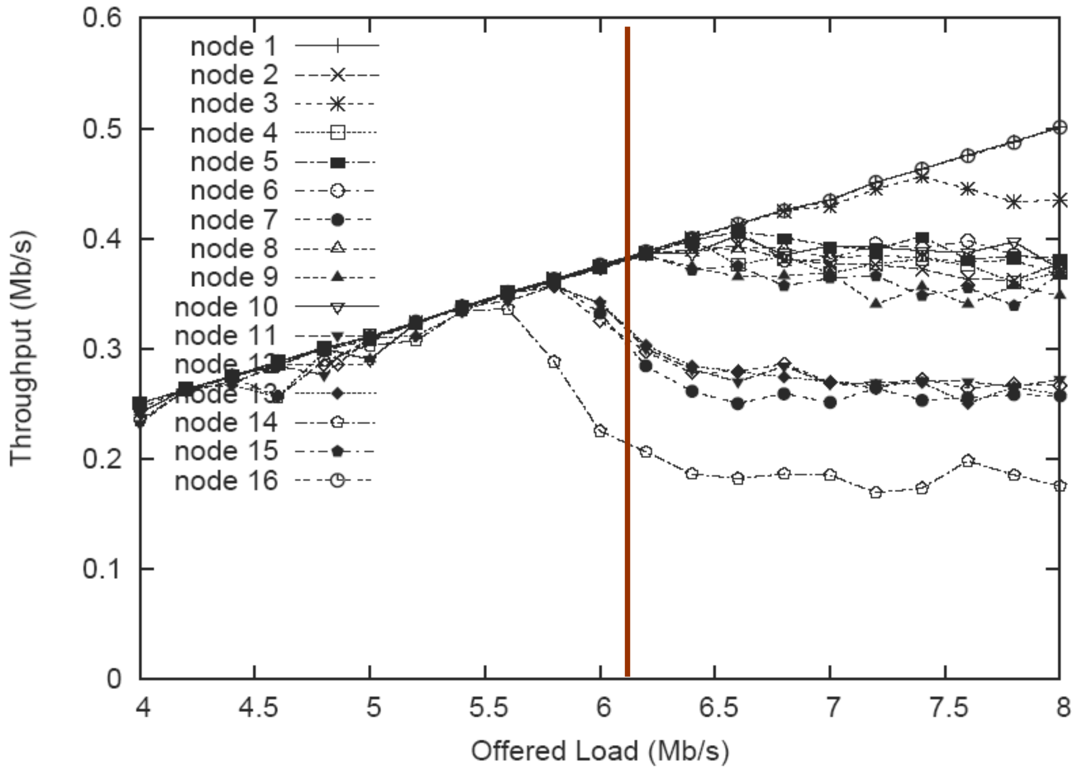


Figure 14: Empirical DCF fairness with respect to individual throughput share as a function of offered load for 16 iPAQs in indoor office environment.

[Choi]

Figure 2 RTS/CTS

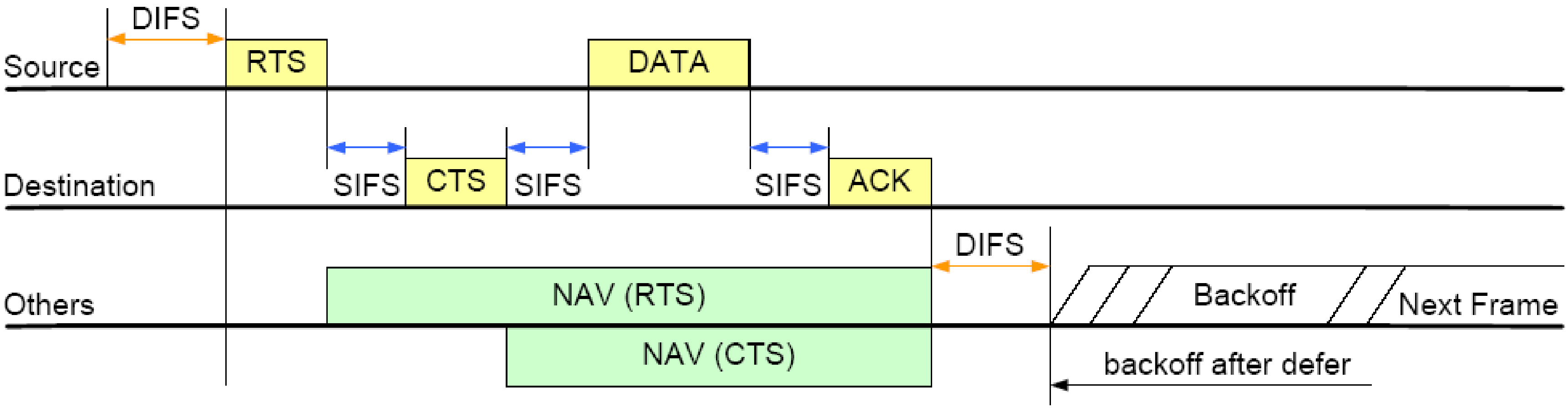


Fig. 2. RTS/CTS exchange mechanism of IEEE 802.11

RTS/CTS Summary

- RTS/CTS can reduce collisions.
- RTS/CTS can guard against and reduce hidden terminals.
- RTS/CTS adds overhead that reduces throughput.
- Normally, RTS/CTS is turned off!

Rate Adaptation Algorithms

AARF	ARF	AMRR
CARA	CROAR	DOFRA
Fast-LA	HRC	LA
LD-ARF	MiSer	MultiRateRetry
MPDU	OAR	ONOE
PER	RBAR	RFT
RRAA	SampleRate	SwissRA

Rate Adaptation Algorithms

1997	ARF			
1998				
1999				
2000				
2001	RBAR			
2002	MPDU	OAR	PER	
2003	LA	MiSer	SwissRA	
2004	AARF	AMRR	HRC	MultiRateRetry
2005	Fast-LA	LD-ARF	RFT	SampleRate
2006	CARA	CROAR	DOFRA	RRAA
2007				

Rate Adaptation Algorithms

- Uses recent history and probes: ARF, AARF, SampleRate
- Long interval smoothing: ONOE, SampleRate
- Multiple rates: MultiRateRetry, AMRR, RRAA
- Uses RTS/CTS: RBAR, OAR, CROAR, CARA
- Uses RSSI to approximate SNR, each node maintains 12 dynamic RSS thresholds: LA
- Puts checksum on header and use NACK to signal link loss error: LD-ARF
- Table lookup with thresholds: HRC,MPDU(len,rSNR,count)
- Fragmentation: DOFRA, RFT
- Miscellaneous: PER, MiSer, SwissRA, Fast-LA

Auto Rate Fallback (ARF)

- When **two** consecutive ACK frames are not received correctly, the second retry and subsequent transmissions are sent at the **next lower** rate and a timer is started.
- When the number of successfully received ACKs reaches **10** or the timer goes off, a **probe frame** is sent at the **next higher** rate. However, if an ACK is NOT received for this frame, the rate is lowered back and the timer is restarted.

ARF and AARF

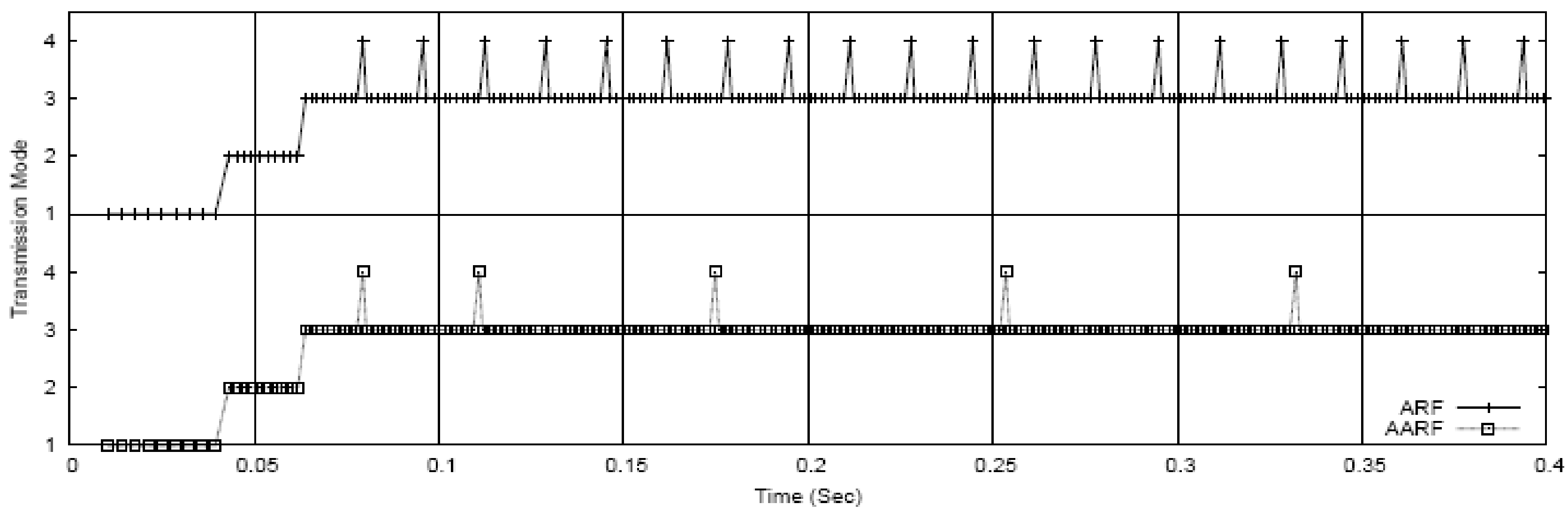


Figure 1: Mode selection comparison between ARF and AARF.

Receiver Based Auto Rate (RBAR)

- Receivers control sender's transmission rate.
- RTS and CTS are modified to contain info on size and rate **{not 802.11 compatible}.**
- Uses analysis of RTS reception (RSSI) to estimate SNR and choice sent back to sender in CTS.
- Receiver picks rate based on apriori SNR thresholds in a lookup table.

Collision Aware Rate Adaptation (CARA)

CARA uses two methods for identifying collisions:

1. RTS probing
2. Clear Channel Assessment (CCA) detection

RTS Probing

RTS Probing Idea:

Assume all RTS/CTS transmission failures after a successful RTS/CTS exchange must be due to channel errors.

(Note – this assumes hidden terminals are not possible.)

CARA-1

- Data frame transmitted without RTS/CTS.
- If the transmission fails, RTS/CTS exchange is activated for the next retransmission. If this retransmission fails **{assume channel quality problem}**, then the rate is lowered.
- If retransmission with RTS/CTS is successful **{assume collision occurred},** stay at same rate and send next frame without RTS/CTS.

Figure 4 ARF and RTS Example

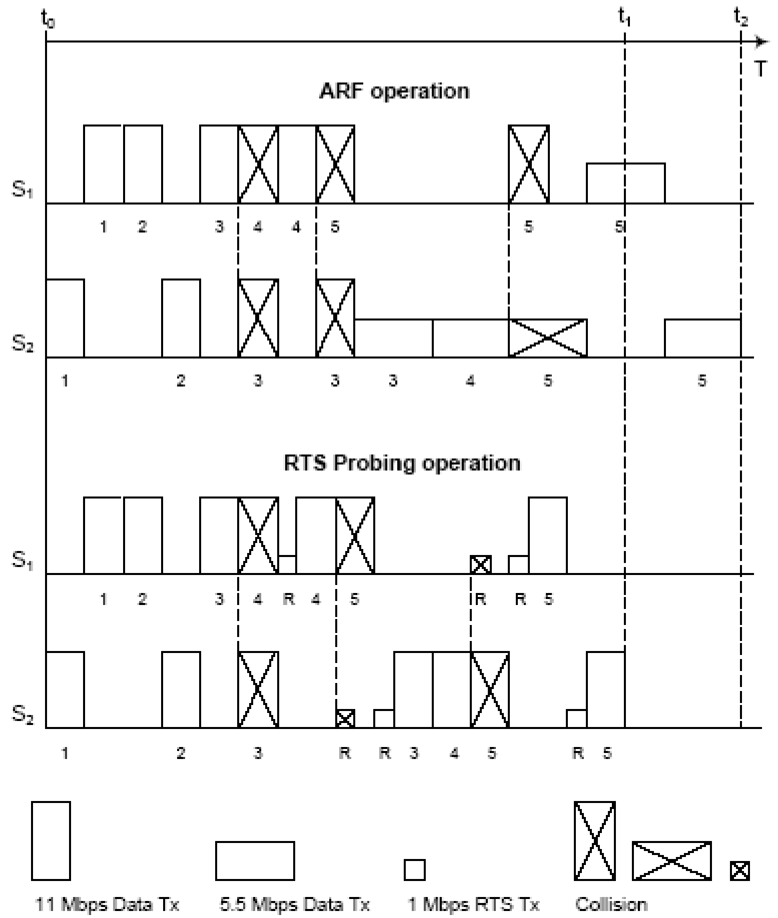


Fig. 4. Illustration of ARF and RTS-Probing timelines for a two-station network, when channel status is good enough to accommodate the highest transmission rate of the 802.11b PHY, i.e., 11 Mbps

Clear Channel Assessment (CCA)

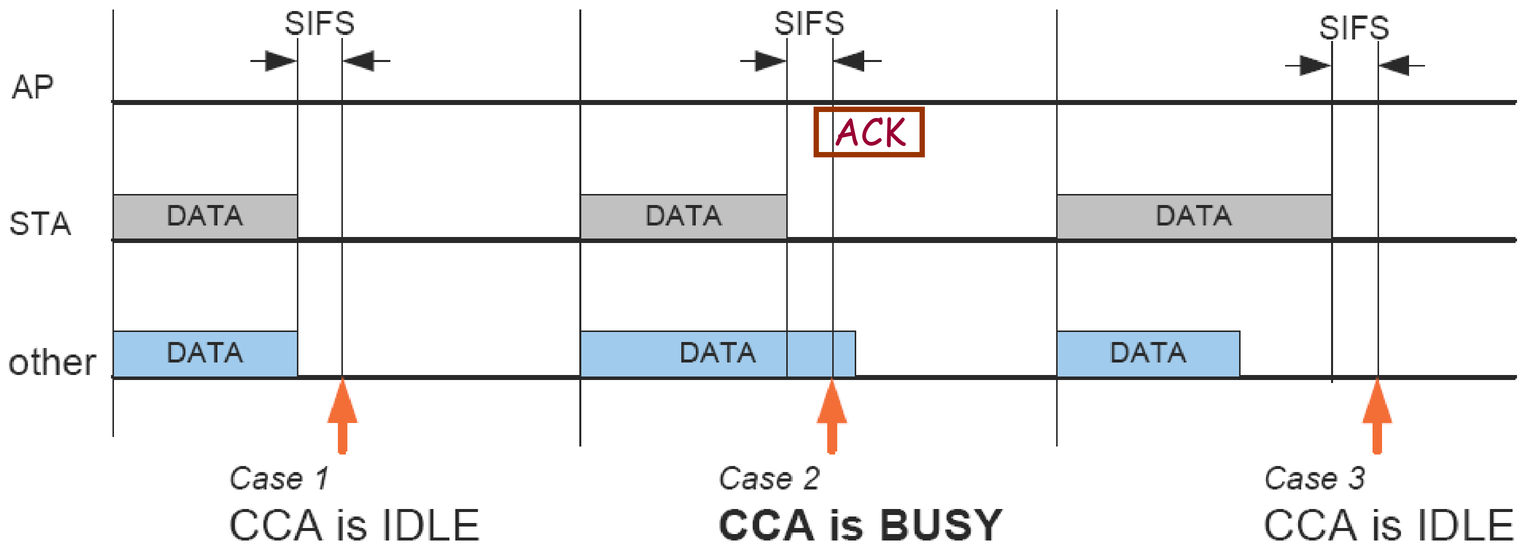


Fig. 5. Three possible cases of collision. In the second case, the collision can be detected via CCA detection.

[J. Kim]

CCA Collision Detection

- Case 2: It is a collision.
  - Transmit without increasing failure count and lowering the transmission rate. No RTS/CTS probe is needed.

- Case 1 and Case 3: Cannot determine that a collision has occurred.
  - Initiate RTS/CTS probe scheme.

Rate Adaptation versus Distance

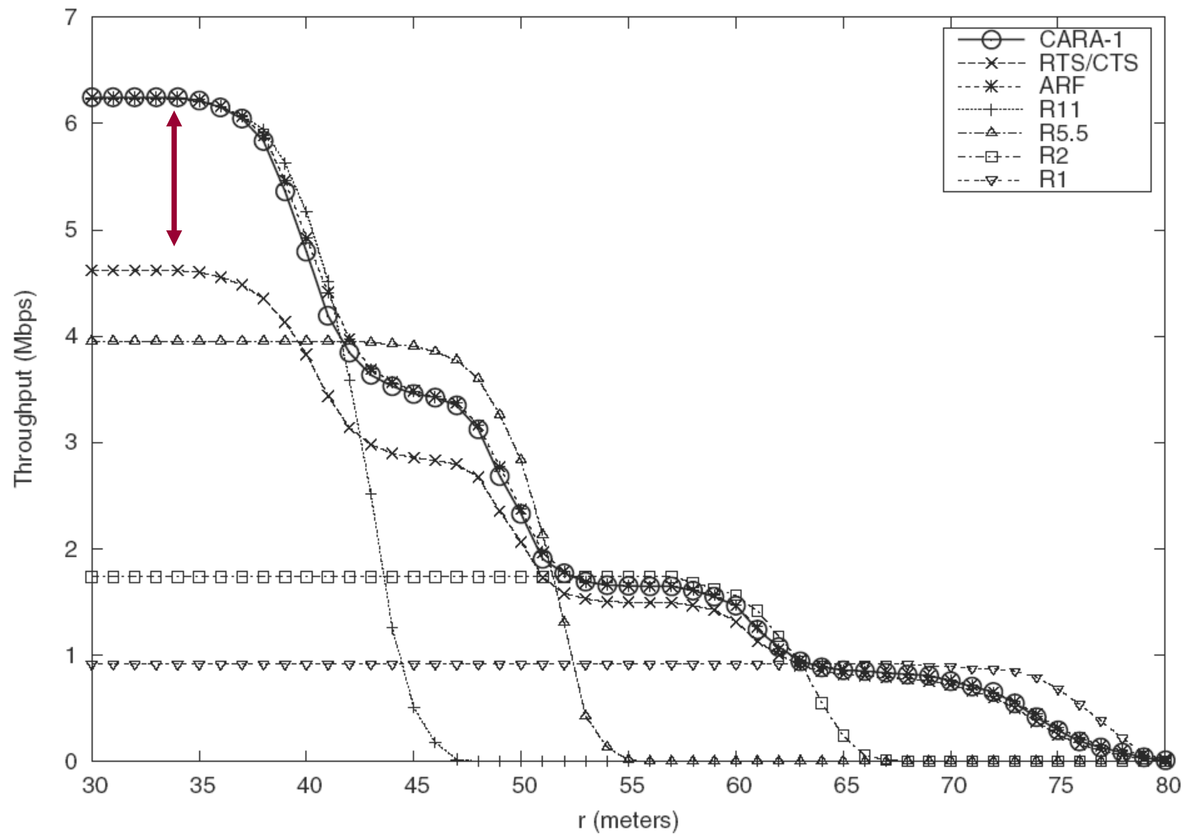


Fig. 6. Throughput comparison of our proposed rate adaptation scheme (CARA-1) against RTS/CTS, ARF, and single-rate schemes for one-to-one topology networks with various distance (r)

NS-2 Simulation Details

- 20dBm transmit power
- Static stations; 1500 octet MAC payload
- BER vs SNR curves measured in AWGN (Additive White Gaussian Noise) environment without fading.
- Set background noise to -96dBm
- Simulate indoor settings
- Use Ricean fading model for multi-path fading time-varying wireless conditions.

CARA-1 Throughput

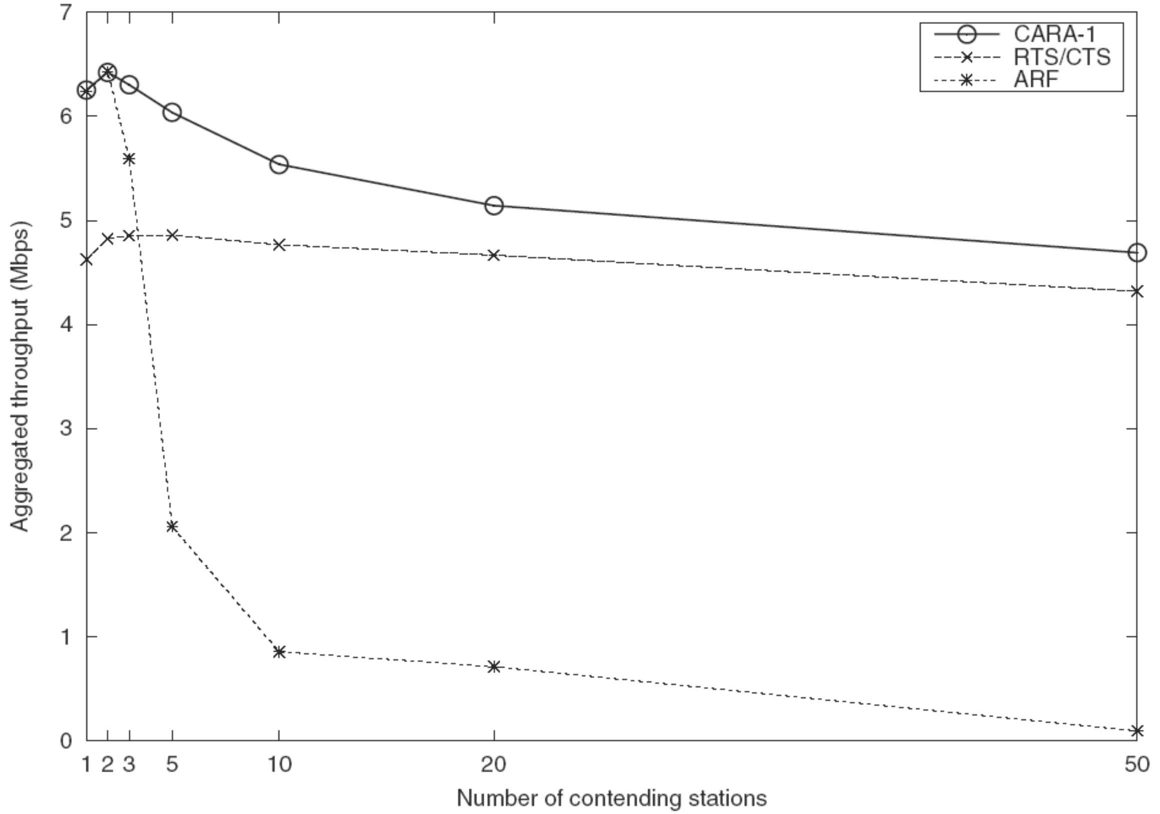


Fig. 7. Throughput comparison of our proposed rate adaptation scheme (CARA-1) against RTS/CTS and ARF for star-topology networks with various number of contending stations

Figure 8 CARA-1 and CARA-2

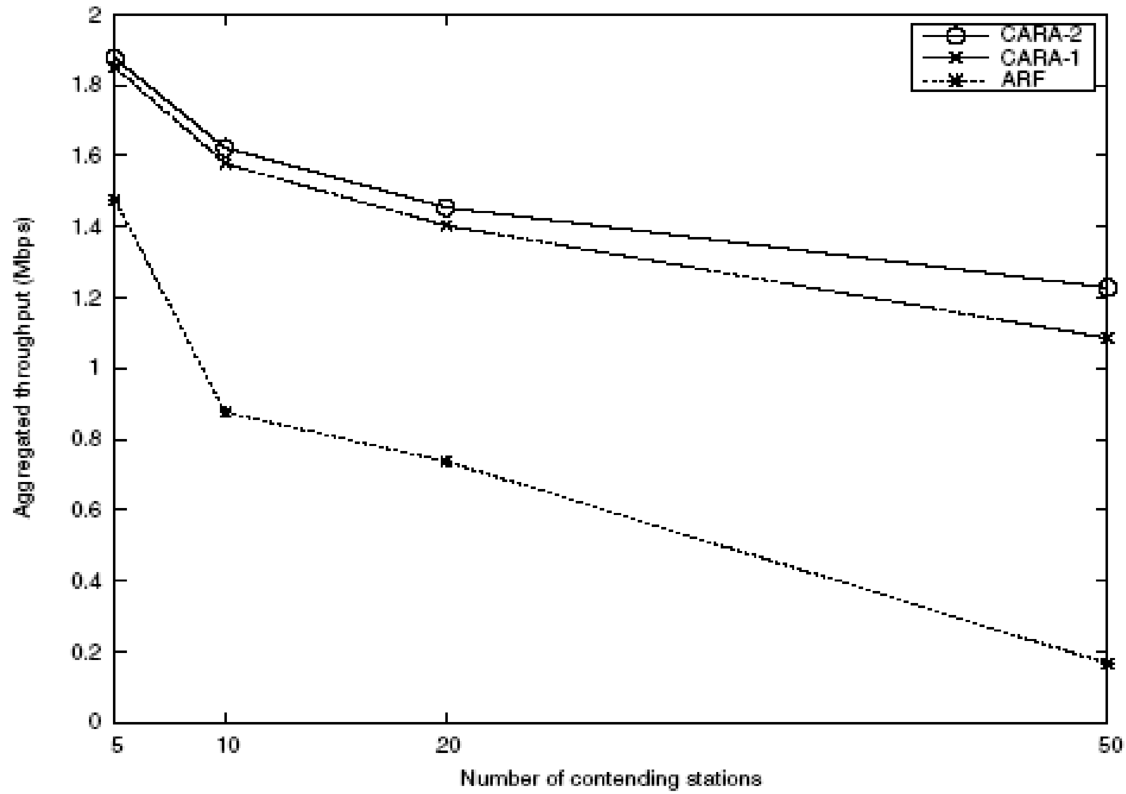


Fig. 8. Throughput comparison of our proposed rate adaptation schemes (CARA-1 and CARA-2) against ARF for line-topology networks with various number of contending stations with randomly chosen data frame sizes and stations' positions

Figure 9a: 50 scenarios

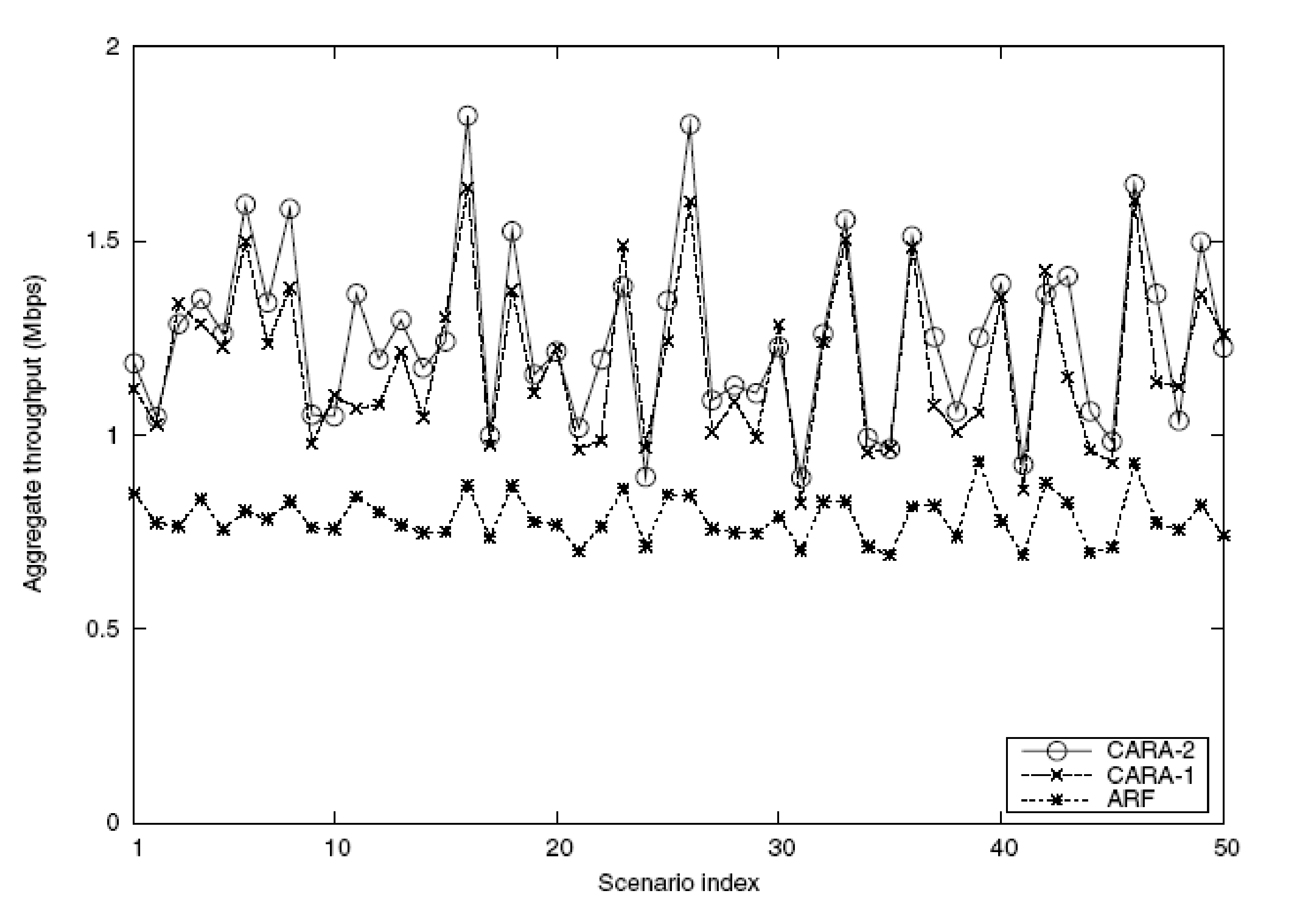


Figure 9b
Varying contending stations

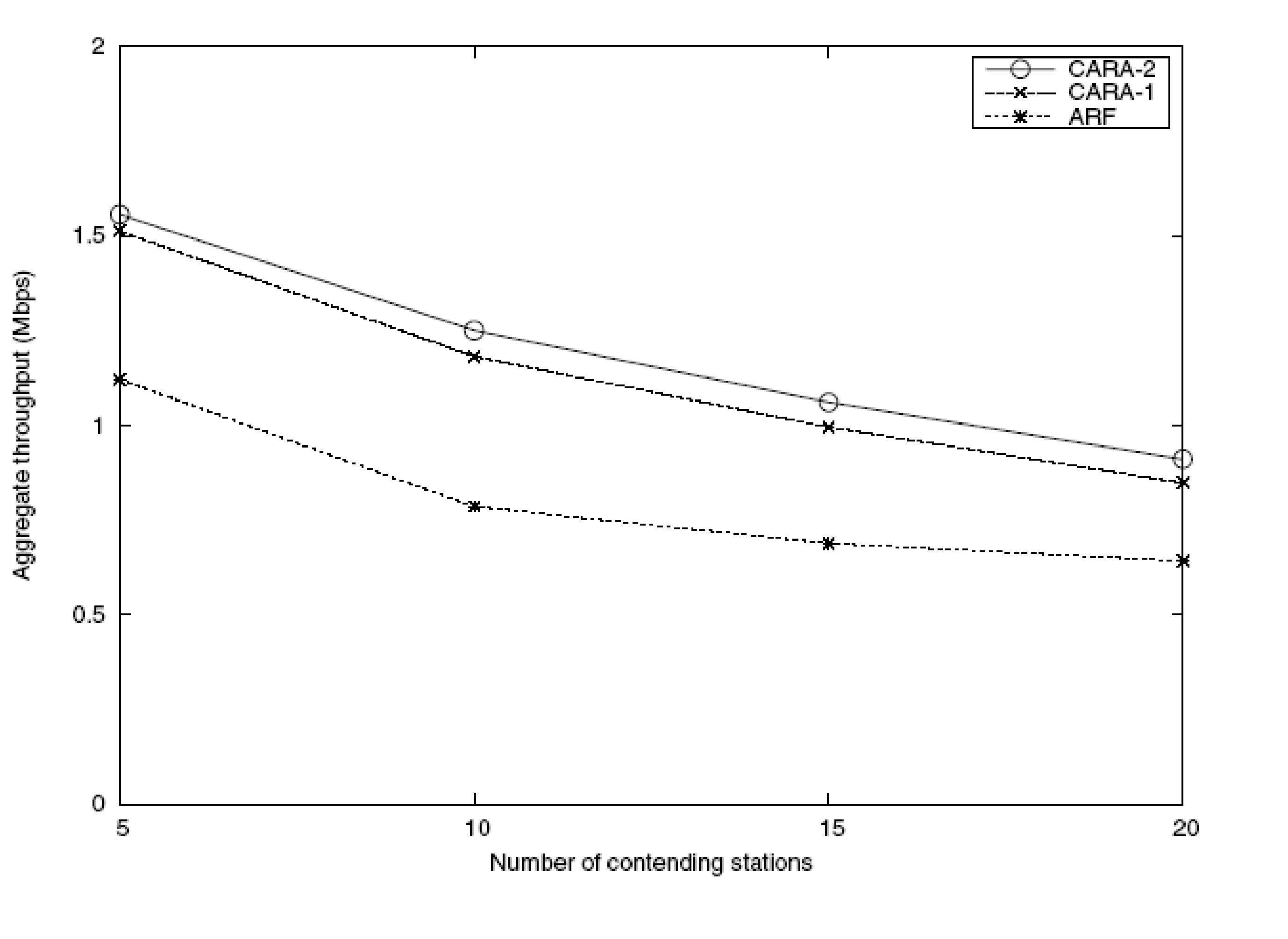
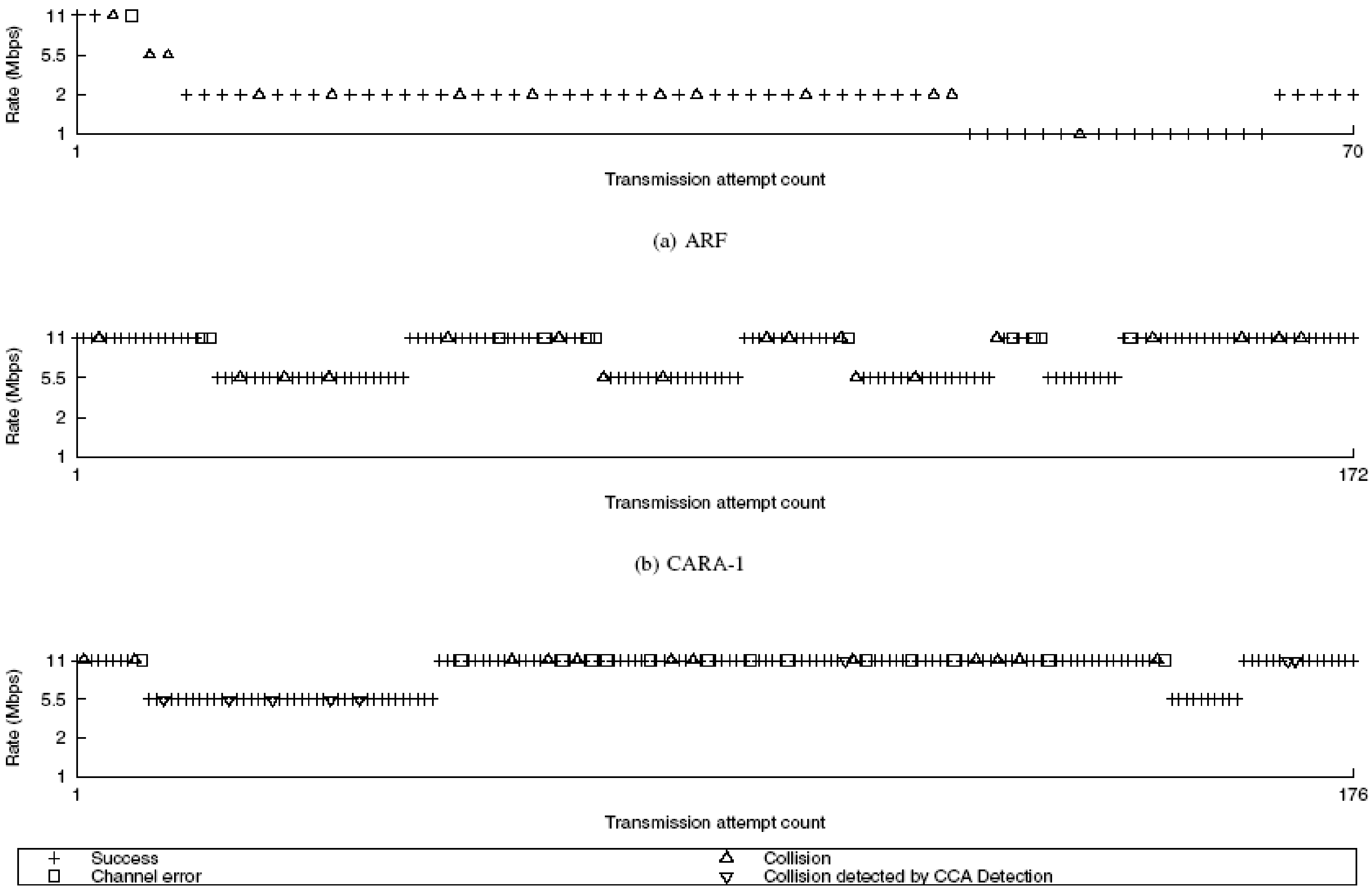


Figure 10 Adaptability Comparison



(a) ARF

(b) CARA-1

(c) CARA-2

Table II

TABLE II

COMPARISON OF THREE TESTING SCHEMES FOR THE 30-SECOND SIMULATION RUN

	ARF	CARA-1	CARA-2
# of tx attempts	1344	3092	3246
# of tx successes	1094	2518	2643
Throughput (Mbps)	1.58	3.37	3.49

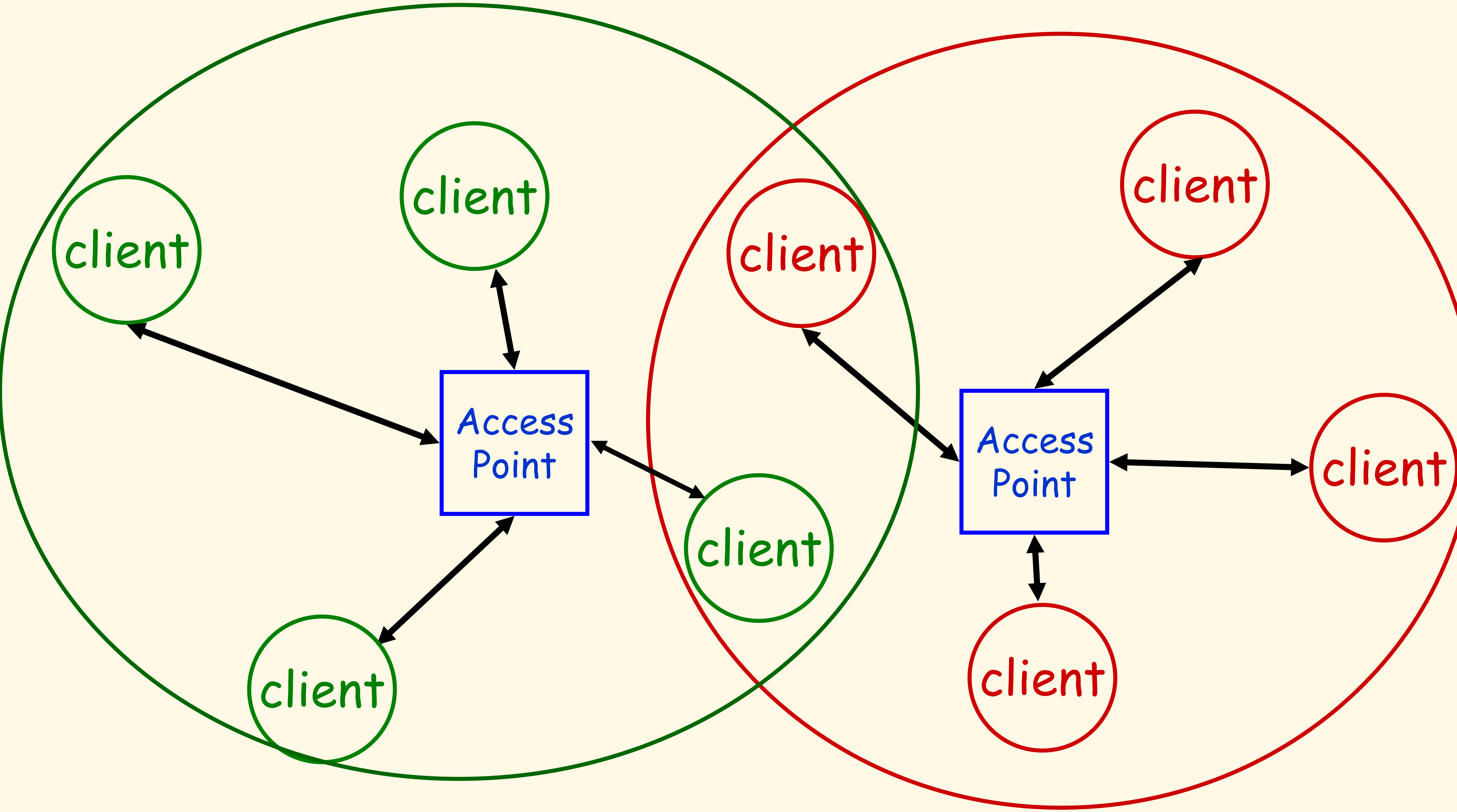
Conclusions

- CARA is more likely to make correct rate adaptation decisions than ARF.
- CARA requires no change to the 802.11 standard (unlike RBAR).
- CARA significantly outperforms ARF in all simulated multiple contending environments.

Future Work

- Look at changes to the increase rate algorithm [CARA-RI].
- Study optimization of operational CARA parameters.
- Address possibility of hidden terminal detection [CARA-HD].
- Built a working CARA prototype using MadWIFI driver.

Multiple APs
multiple clients (heterogeneous)



Hidden Terminals

Without a hidden terminal, loss ratio ~5.5%.

One hidden AP with mild sending rate (0.379 Mbps) yields:

	ARF	AARF	SampleRate	FixedRate
Goodput (Mbps)	0.65	0.56	0.58	1.46
Loss Ratio	61%	60%	59%	60%

Table 1: Performance of different rate adaptation algorithms in the presence of hidden stations.

[Wong]

Future Work Results

Seongkwan Kim, Sunghyun Choi, Daji Qiao, and Jongseok Kim

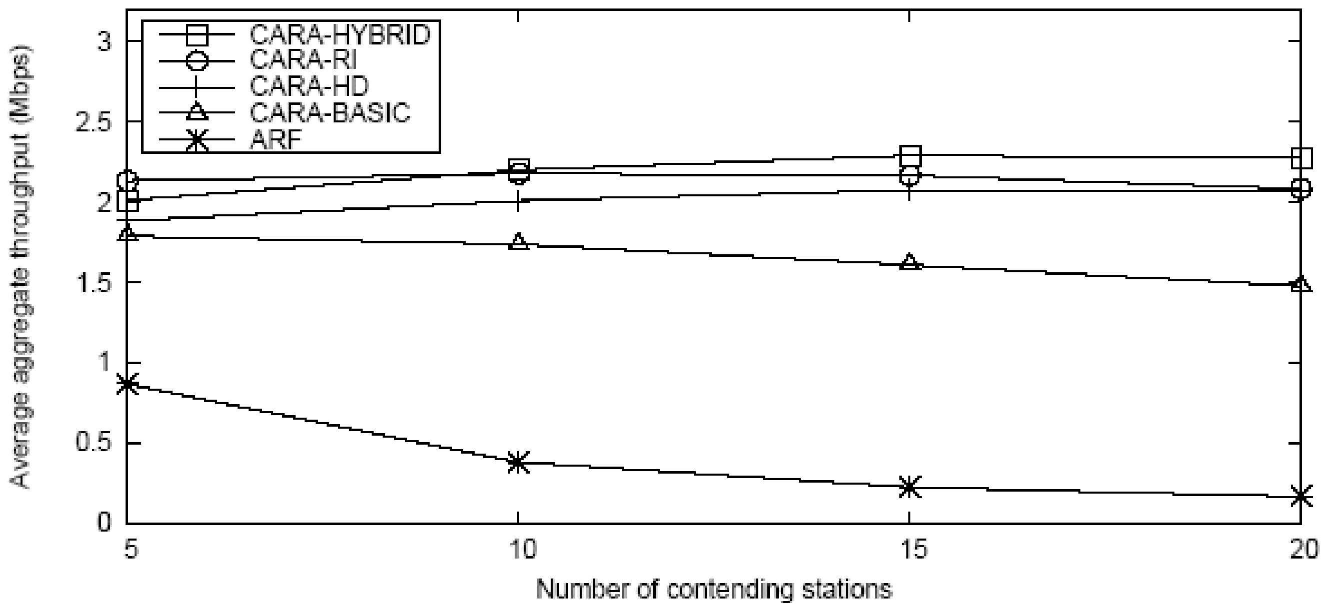


Fig. 1. Throughput comparison in random-topology networks.

Questions?

Collision Aware Rate Adaptation (CARA)