CORA

COgnitive Rate Adaptation

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Outline

- Introduction
- The Rate Adaptation problem
- Proposed algorithm
  - CogProt framework
  - COgnitive Rate Adaptation
- Performance evaluation
- Conclusions

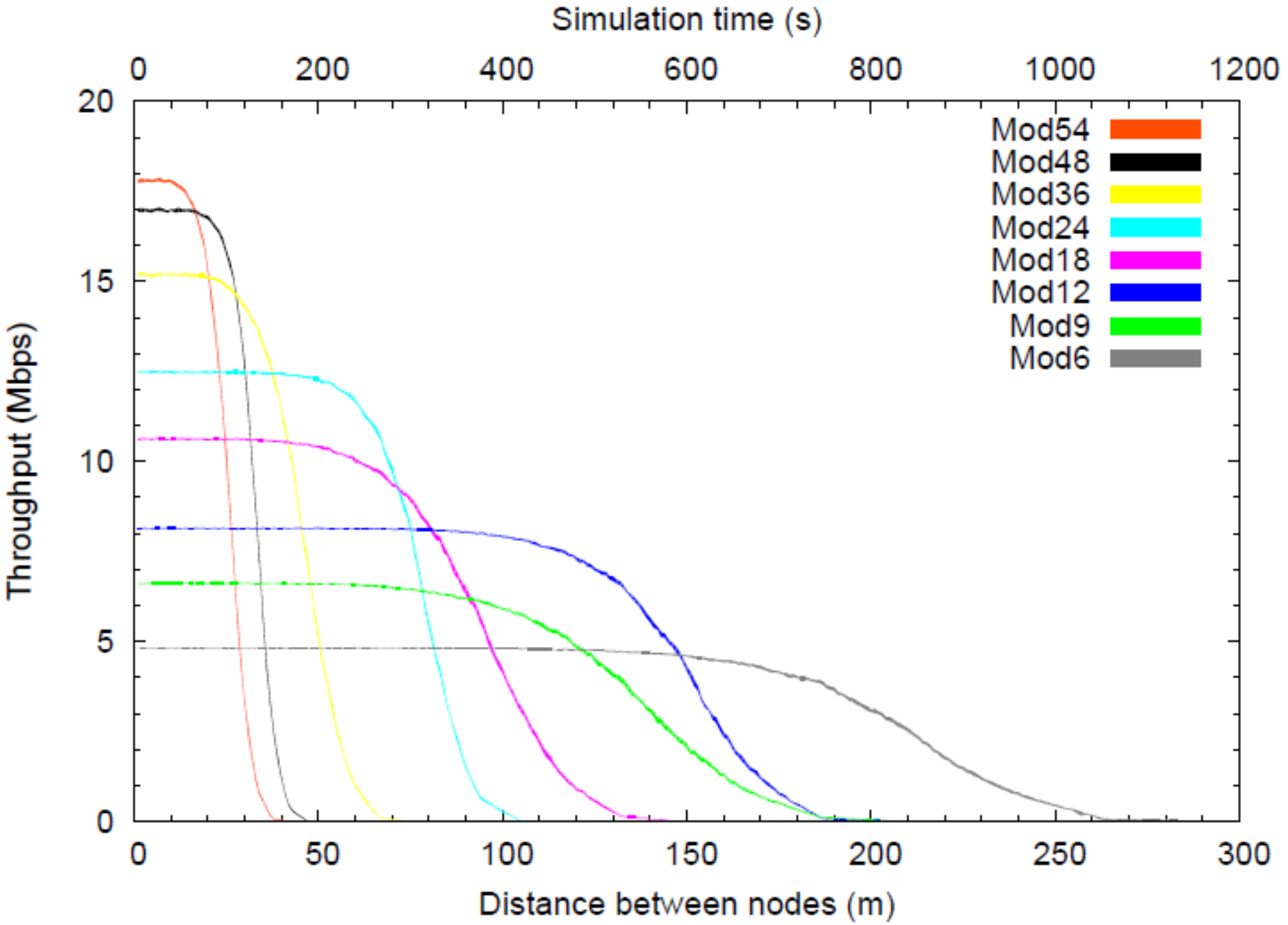
Introduction

- Wireless networks have emerged as the key building blocks of the future Internet
- Affordable devices and high data rates
- These high data rates are possible through new modulation schemes
  - Take advantage of good channel conditions
  - More sensitive to medium quality degradation
  - Do not perform well for long range transmissions

Introduction

- Wireless medium suffers from unstable channel conditions
- Development of several modulation schemes
  - Provide high data rate in good channel conditions, and resilient connection as the channel degrades
- IEEE 802.11 offers several modulation schemes, each one attached to a nominal data rate
  - IEEE 802.11 g: 6, 9, 12, 18, 24, 36, 48 and 54 Mbps

    (achievable throughput is lower than the nominal rate)


Simulation time (s)
0
200
400
600
800
1000
1200
20
15
10
5
0
Throughput (Mbps)
Mod54
Mod48
Mod36
Mod24
Mod18
Mod12
Mod9
Mod6
0
50
100
150
200
250
300
Distance between nodes (m)

The Rate Adaptation problem

- Rate adaptation consists of assessing the wireless channel conditions and selecting the most appropriate modulation scheme
  - The goal is to select the modulation scheme that will optimize network performance
  - We can look for improving throughput, mitigating Packet Error Rate, reducing delay, etc
  - The most common metric is throughput

Existing solutions

- The absence of a standard solution motivated the proposal of several algorithms

1) Use of statistical information to guide the rate selection
   - ARF [2]: Increase or decrease the rate accordingly to number of successes or failures on consecutive transmission attempts
   - Statistics-based mechanisms present long convergence time and are affected by the difficulty of finding proper thresholds.

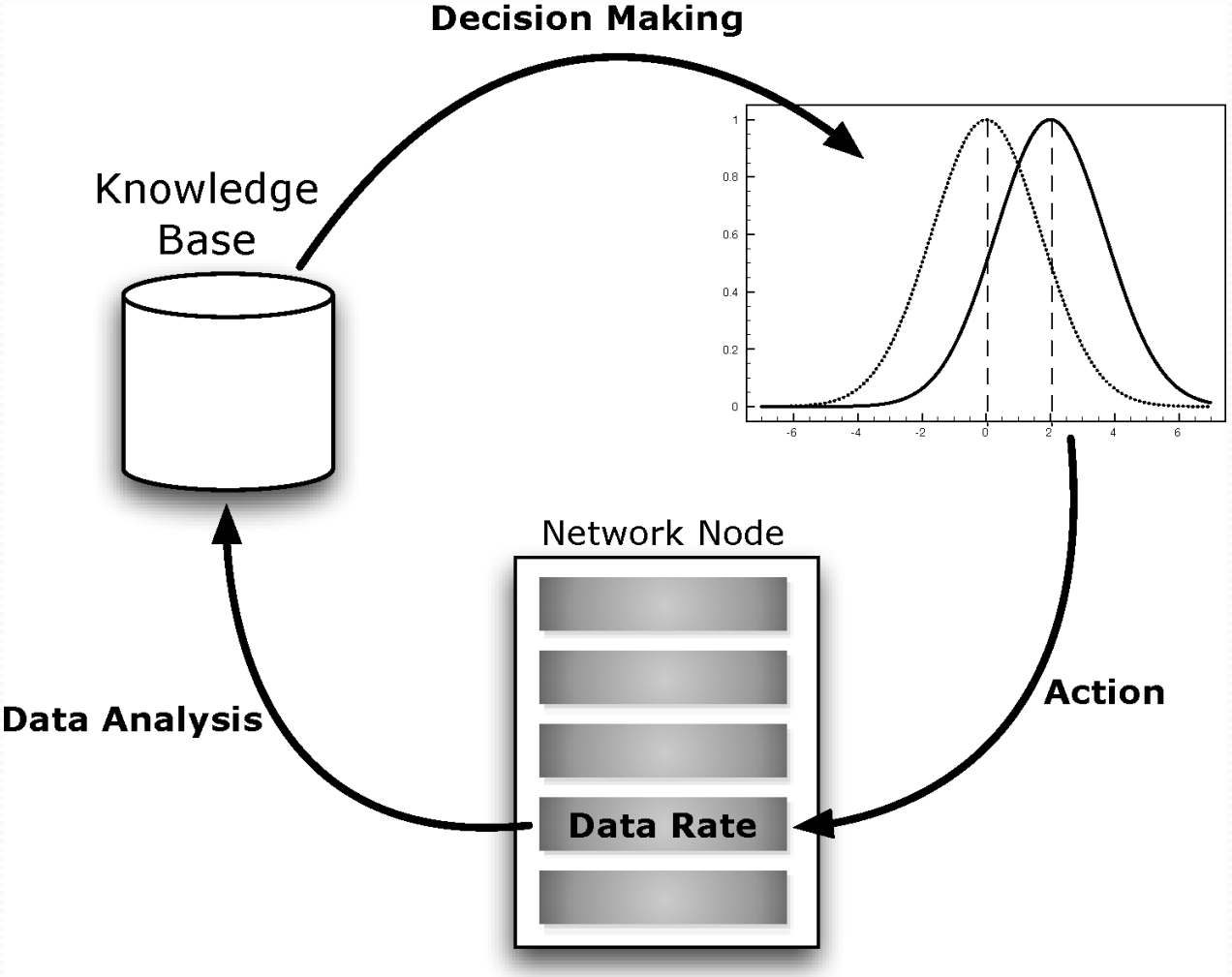
Existing solutions

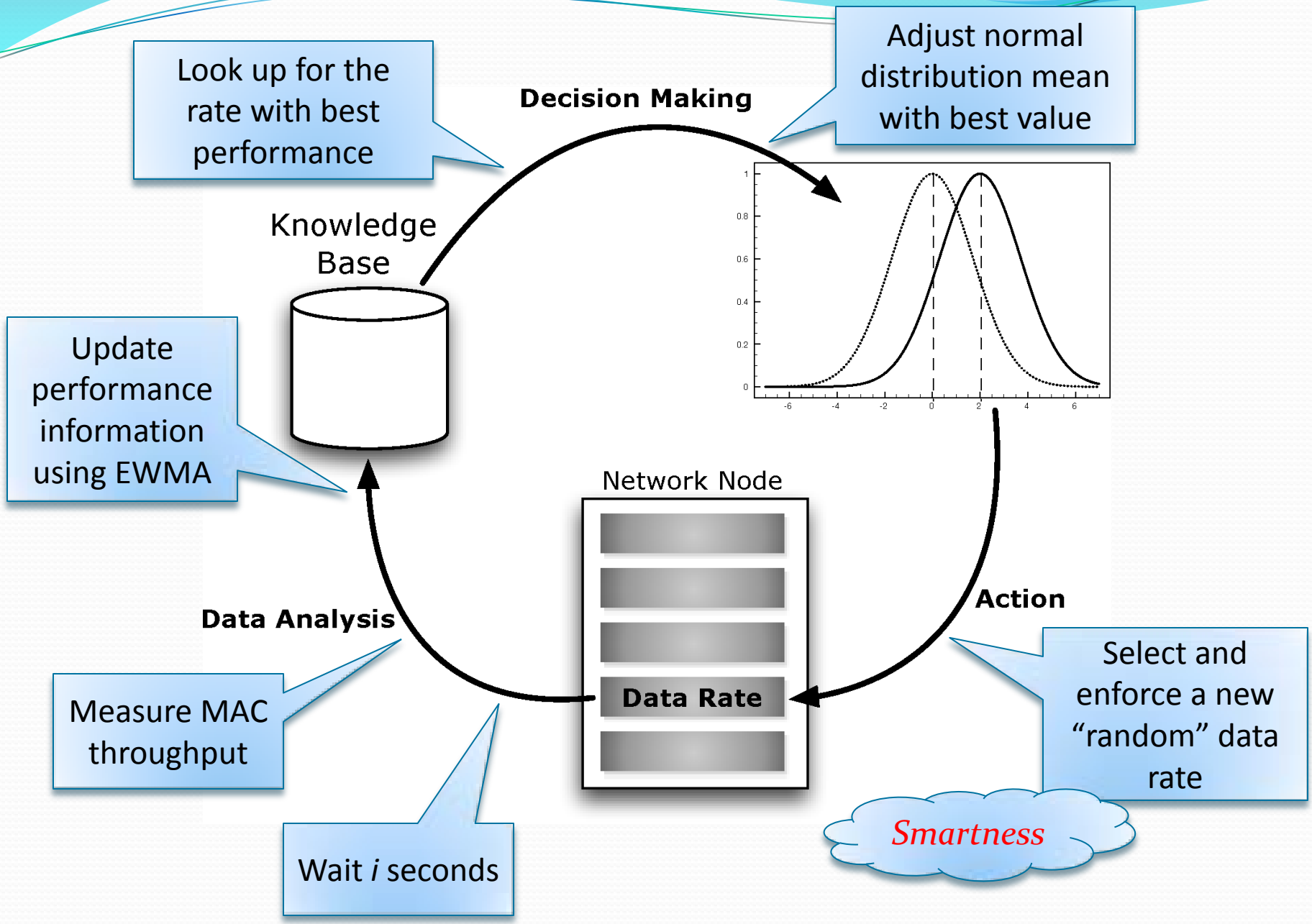
2) Use the signal-to-noise ratio (SNR) to measure channel conditions

- RBAR [3]: Uses RTS/CTS messages to get feedback on channel quality from the receiver to determine the optimal rate at the sender
- Signal-based mechanisms introduces communication overhead, and suffer from the lack of a correlation between SNR and the delivery probability at a given data rate, limiting effectiveness of this approach in practice

Proposed algorithm

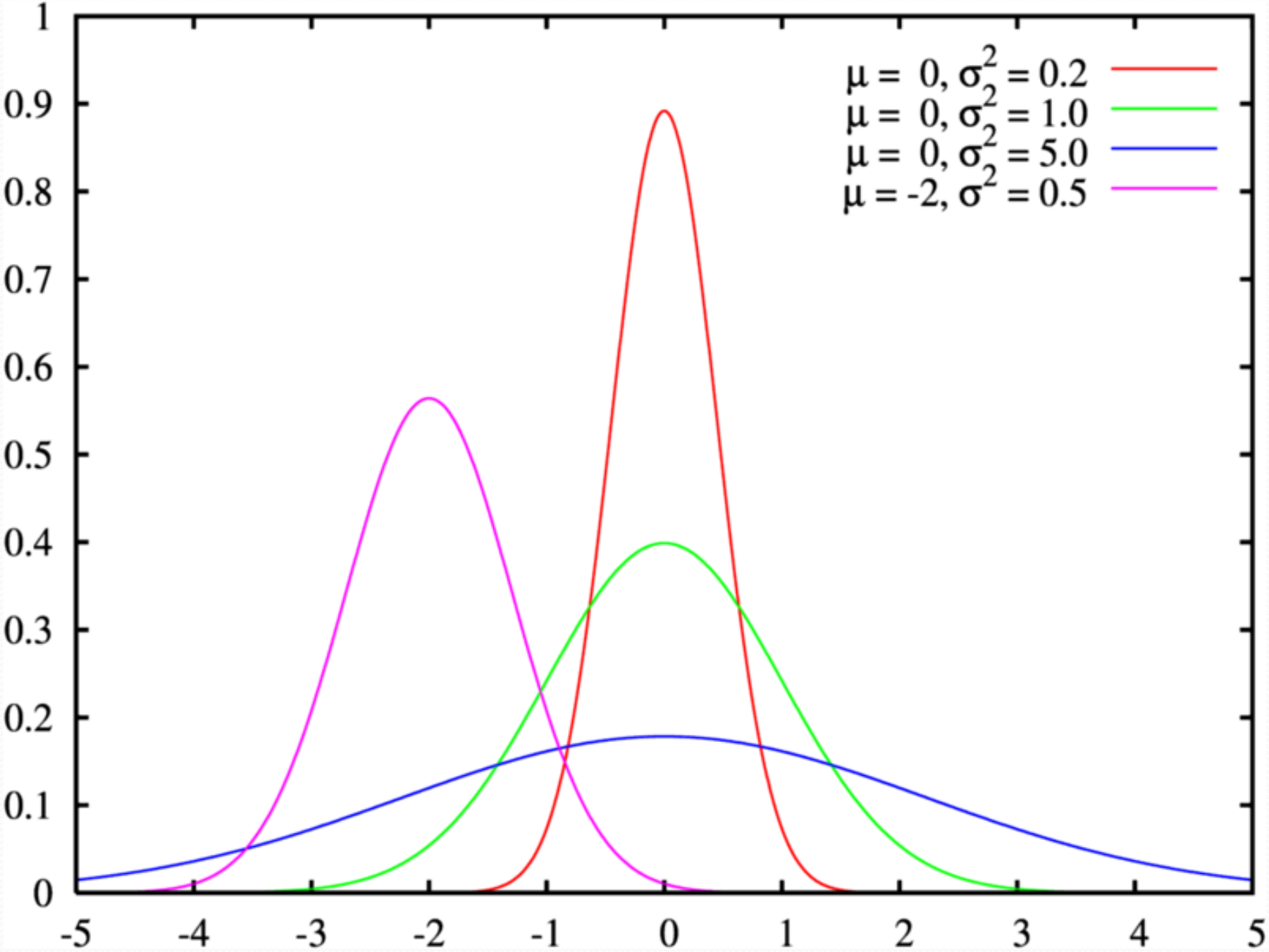
- A COgnitive Rate Adaptation algorithm – CORA
  - It's based on CogProt:
    - A framework for cognitive configuration and optimization of communication protocols
    - Considers the concept of Cognitive Networks
    - Deal with performance degradation and provide dynamic reconfiguration
  - Introduces a Cross-Layer Cognitive Plane


Decision Making
Knowledge Base
Network Node
Data Rate
Data Analysis
Action


Look up for the rate with best performance
Decision Making
Adjust normal distribution mean with best value
Knowledge Base
Update performance information using EWMA
Network Node
Data Rate
Data Analysis
Action
Measure MAC throughput
Wait *i* seconds
Select and enforce a new "random" data rate
Smartness

Cognitive Rate Adaptation

- The key is how to select this "random" rate based on the available (knowledge) information
  - Use a Normal Distribution that describes data that clusters around a mean
  - Selects as mean the best rate at the current cycle (which reflects current network state)
  - The mean converges to the optimal value (rate)
  - Most of the random chosen values are optimal under current network conditions
  - Eventually test neighboring values, allowing adjustments


μ = 0, σ² = 0.2
μ = 0, σ² = 1.0
μ = 0, σ² = 5.0
μ = -2, σ² = 0.5
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-5
-4
-3
-2
-1
0
1
2
3
4
5

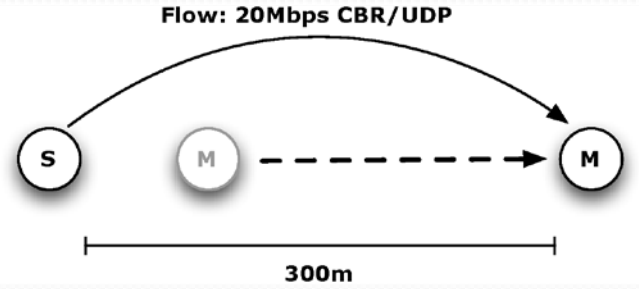
Cognitive Rate Adaptation

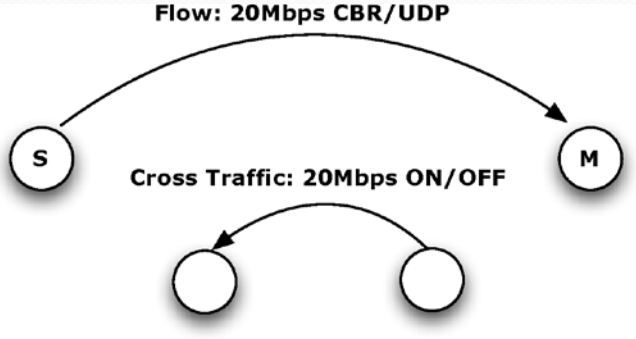
- CORA control parameters setup
  - Performance metric ***m***: ***MAC throughput***
  - Sample interval ***i***: ***0.1 sec***
    - Ranging from 0.01s up to 8s
  - EWMA recent significance factor ***α***: ***0.9***
    - Ranging from 0.0 up to 0.9
  - Normal Distribution Standard Deviation ***μ***: ***0.3*** (90%)
    - Ranging from 0.2 up to 1.5

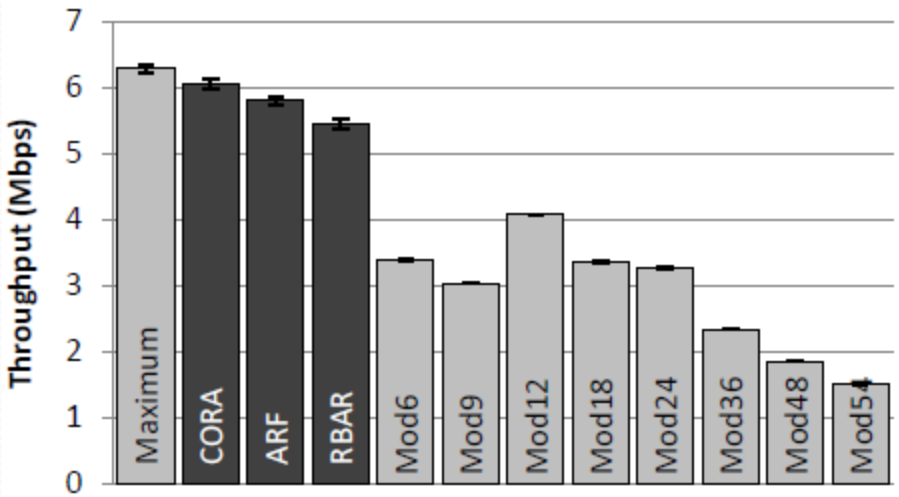
Performance evaluation

- Using Network Simulator *ns-2* with the module dei80211mr
- Results compared against ARF and RBAR
- Using IEEE802.11g with free space propagation model and DSDV routing protocol
- Results are the average from at least 10 iterations with 95% confidence interval

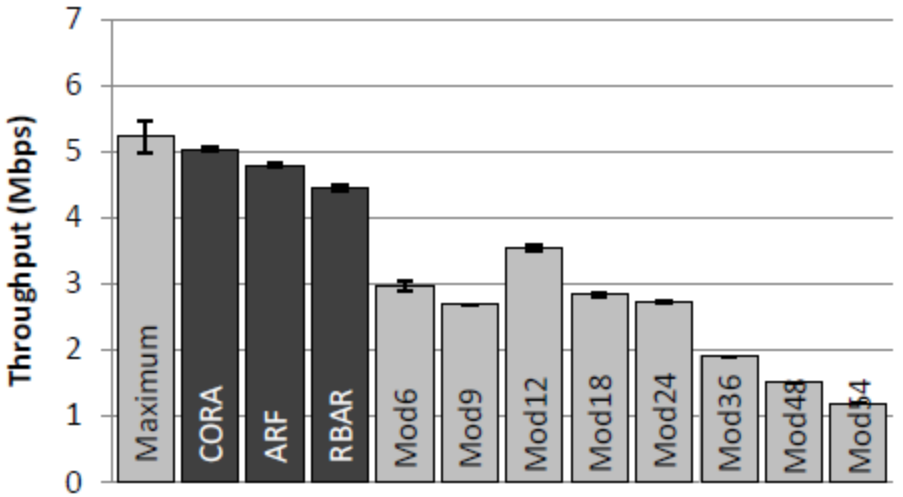
Scenario configurations



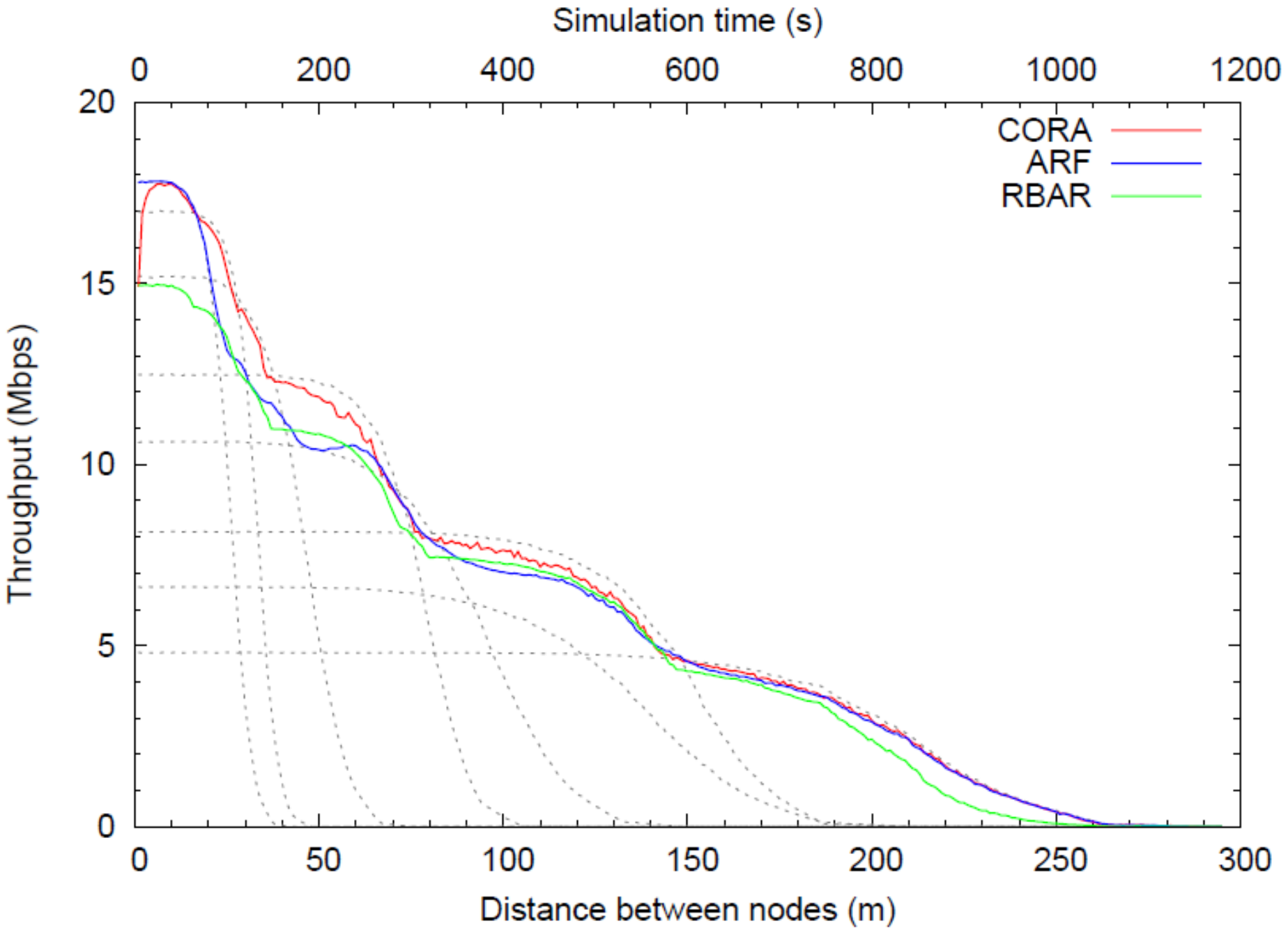




(a) Only two nodes



(b) Two nodes with cross-traffic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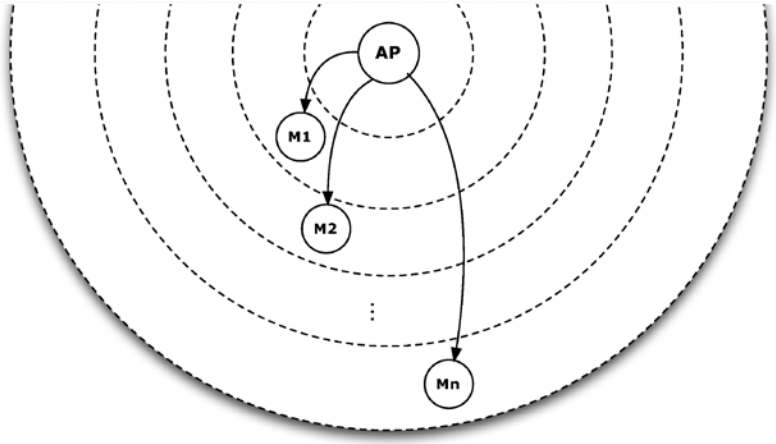
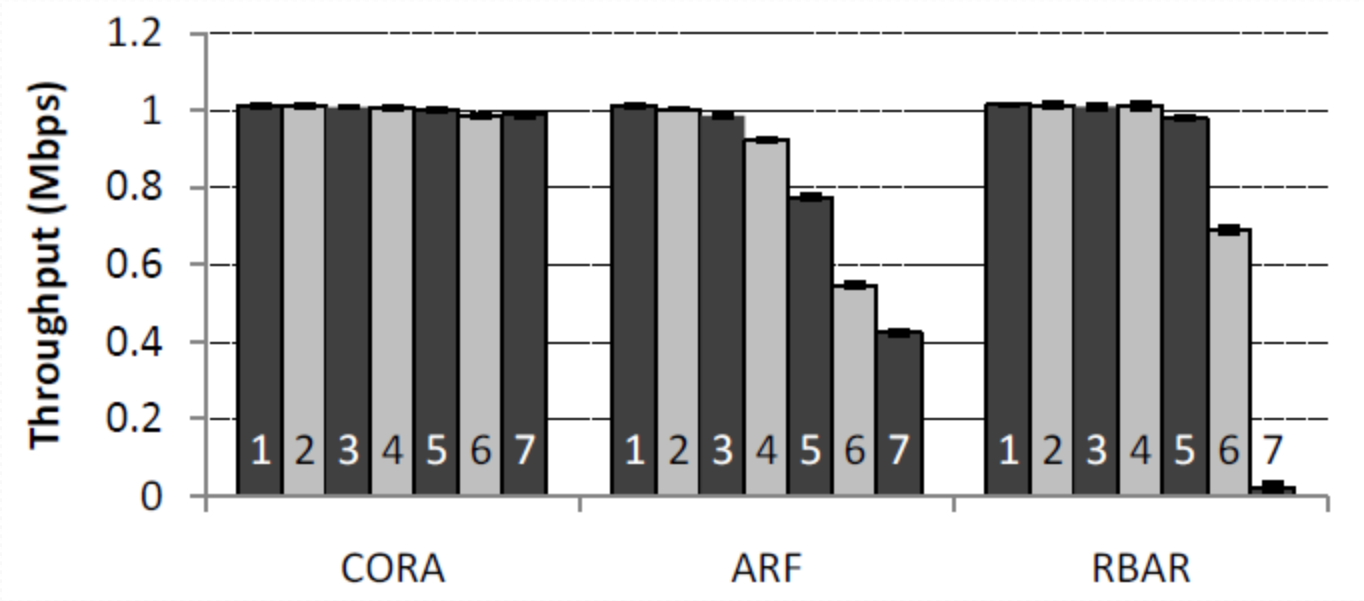
Throughput (Mbps)
CORA
ARF
RBAR
0
50
100
150
200
250
300
Distance between nodes (m)

Multiple Destinations





Conclusions

- Simple and deployable solution
- Don't introduce RTS/CTS overhead
- Support different optimization metrics
- Converge to the best rate and be able to react to channel condition changes
- Avoid the need of loss differentiation

Conclusions

- The feedback loop is performed by each element in an independent way
- Completely decentralized system
- Elements enabled with CORA can work together with elements that run/perform another rate adaptation algorithm (or none)

References

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2. Kamerman, A., Monteban, L.: *WaveLAN-II:* **A High-Performance Wireless LAN for the Unlicensed Band**. *Bell Labs Technical Journal* 2(3) (1997) 118–133
3. Holland, G., Vaidya, N., Bahl, P**.: A Rate-Adaptive MAC Protocol for Multi-Hop Wireless Networks**. *In: MobiCom '01: Proc. of the 7th Conference on Mobile Computing and Networking*, New York, USA, ACM Press (2001) 236–251

Acknowledgments