A Relay-Aided Media Access (RAMA) Protocol in Multirate Wireless Networks

IEEE Transactions on Vehicular Technology
Vol. 55, No. 5, September 2006

林咨銘
2006/12/8
tmlin@itri.org.tw

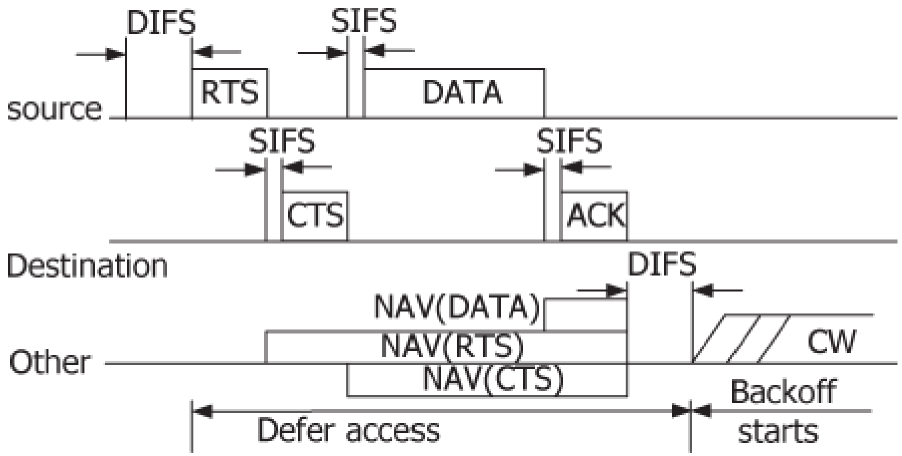
Outline

- Introduction
- Background and related works
- Motivation
- Relay-Aided Media Access (RAMA) Protocol
- Simulation Results
- Conclusion

Introduction

- In WLAN, transmission rate is dependent on Signal-to-Noise Ratio (SNR)
  - When the SNR is sufficiently high, higher data rates can be explored
  - IEEE 802.11 supports multirates, e.g. 11a : 6,8,12,18,…, and 54 Mbps
- Signal attenuation over radio link typically varies as d^n for $2<n<6$, where d is the distance between the sender and the receiver
- Objective
  - Replace one low-rate link with two much higher rate links to improve transmission rate
  - An enhanced multirate IEEE 802.11 protocol is introduced

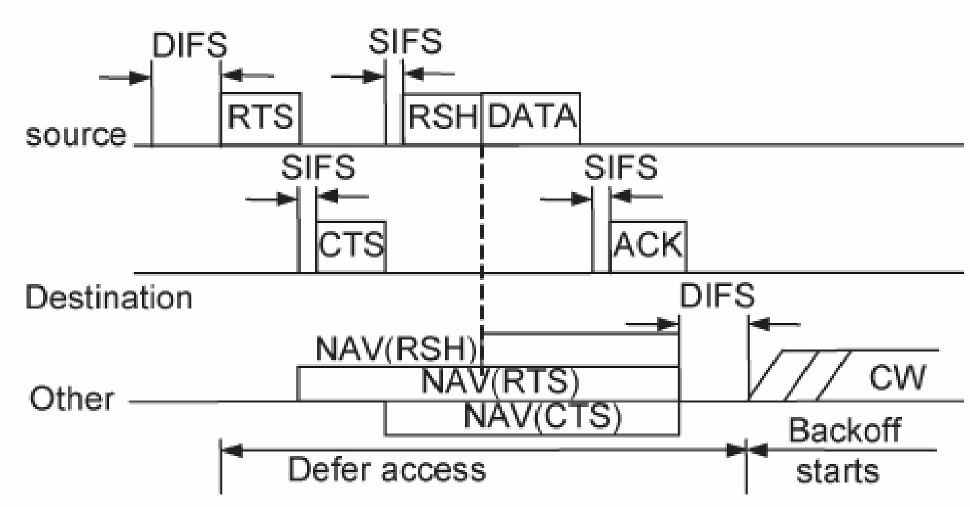
Background



RTS/CTS access mechanism in DCF

- Basic Mechanisms in IEEE 802.11
  - Distributed Coordination Function (DCF)
  - 2-way and 4-way handshaking
  - Network Allocation Vector (NAV)

Related Work



NAV set by other nodes in RBAR

- Receiver-Based AutoRate (PBAR) protocol
  - Receiver selects the appropriate rate for data frame during RTS/CTS frame exchange
  - Maximum possible transmission rate is selected by analyzing the PHY BER of received RTS frame
  - A reservation subheader is inserted preceding data transfer
    - For modifying the NAV value

Motivation

R : transmission rate
W : bandwidth
Pr : received power
Pt : transmitted power
K : constant

- Shannon formula

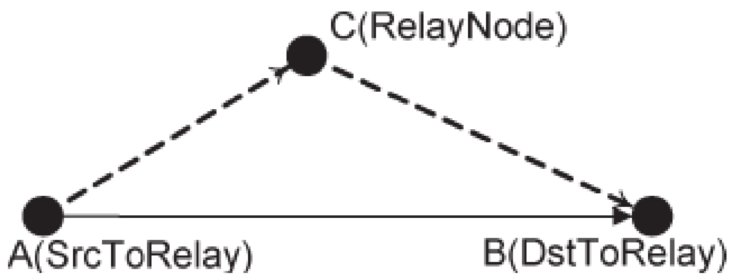
$$R = W \log(1 + \mathrm{SNR})$$

- Propagation model [6]

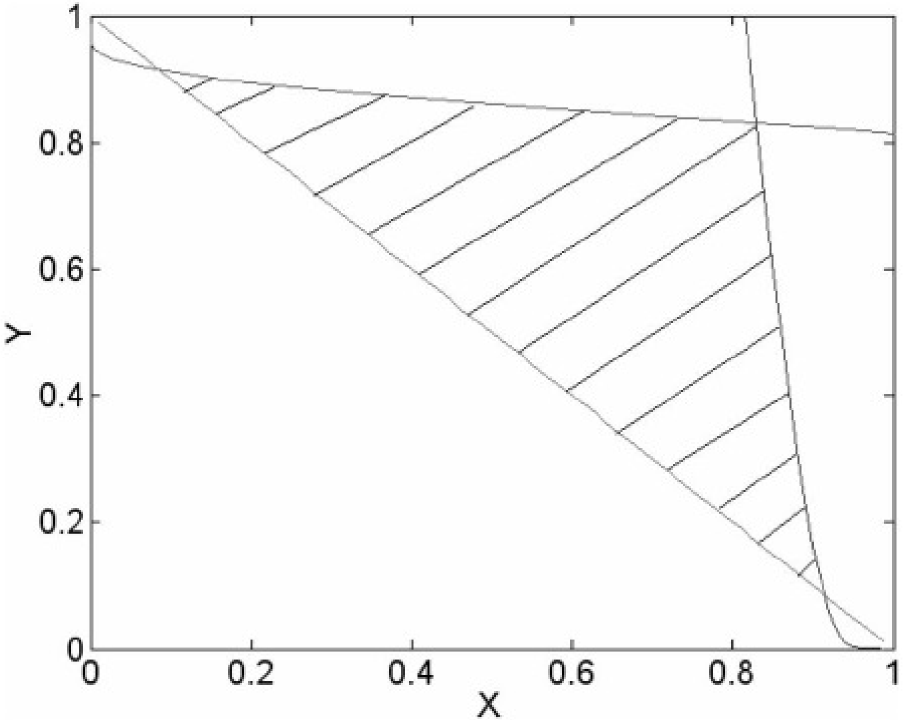
$$P_r = K\frac{P_t}{d^n}$$

- Goal : reduce transmission time

=> $T_{AC} + T_{CB} + SIFS < T_{AB}$



Motivation



Theoretical probability

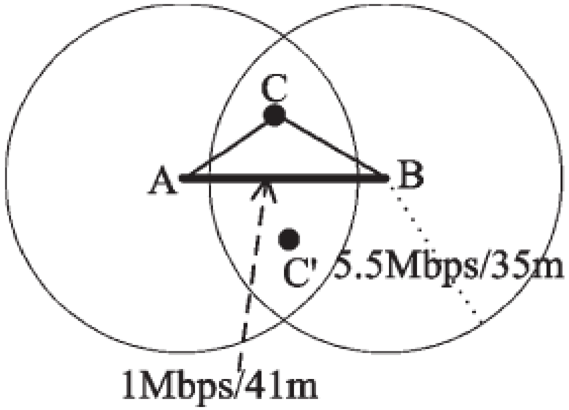
$$\begin{cases} \frac{L}{W\ \log(1+\mathrm{SNR}/x^n)} + \frac{L}{W\ \log(1+\mathrm{SNR}/y^n)} \\ \quad +T_{\mathrm{overhead}} + \mathrm{SIFS} < \frac{L}{W\ \log(1+\mathrm{SNR})} \\ x+y>1 \end{cases}$$

Letting $x = d_{AC}/d_{AB}$ and $y = d_{CB}/d_{AB}$

It is possible to improve transmission rate by replacing one low-rate link with two high-rate links

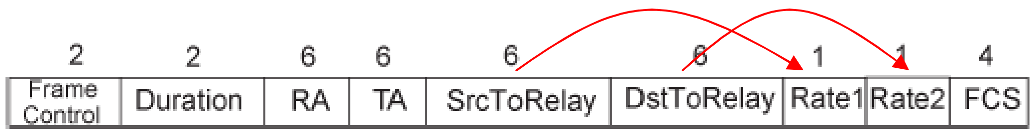
RAMA Protocol Concept

- When node C finds that A is communicating with B at low bit rate
  - C produces an ***invitation*** frame and sends it according to DCF
- After A receives the invitation from C
  - A will record it in its Relay List
  - Other relay candidates C' will cancel their invitation from AB after hearing the invitation from C
- When A sends data packets to B, it will use C as a relay node
  - When C receives the relayed frame from A, it ***forwards*** that immediately after SIFS



RAMA Protocol – Invitation Trigger

- Conditions
  - The communication pairs are both RAMA capable
  - 4-way shaking (RTS/CTS) is used
  - Invitation is sent at the basic rate
    - All possible relay nodes can hear
  - Relay condition is satisfied
  - Data frame is followed immediately by ACK frame
  - Addresses is not changed during relay transmissions



Format of invitation frame

RAMA Protocol – Invitation Trigger

- Solving hidden terminal problem - Serve Table
  - A node does not send an invitation during backoff interval (BI) after it sends out an invitation or acts as relay for the pair
  - Double corresponding BI when it sends out invitation and finds that the pair of nodes still communicate with low rate

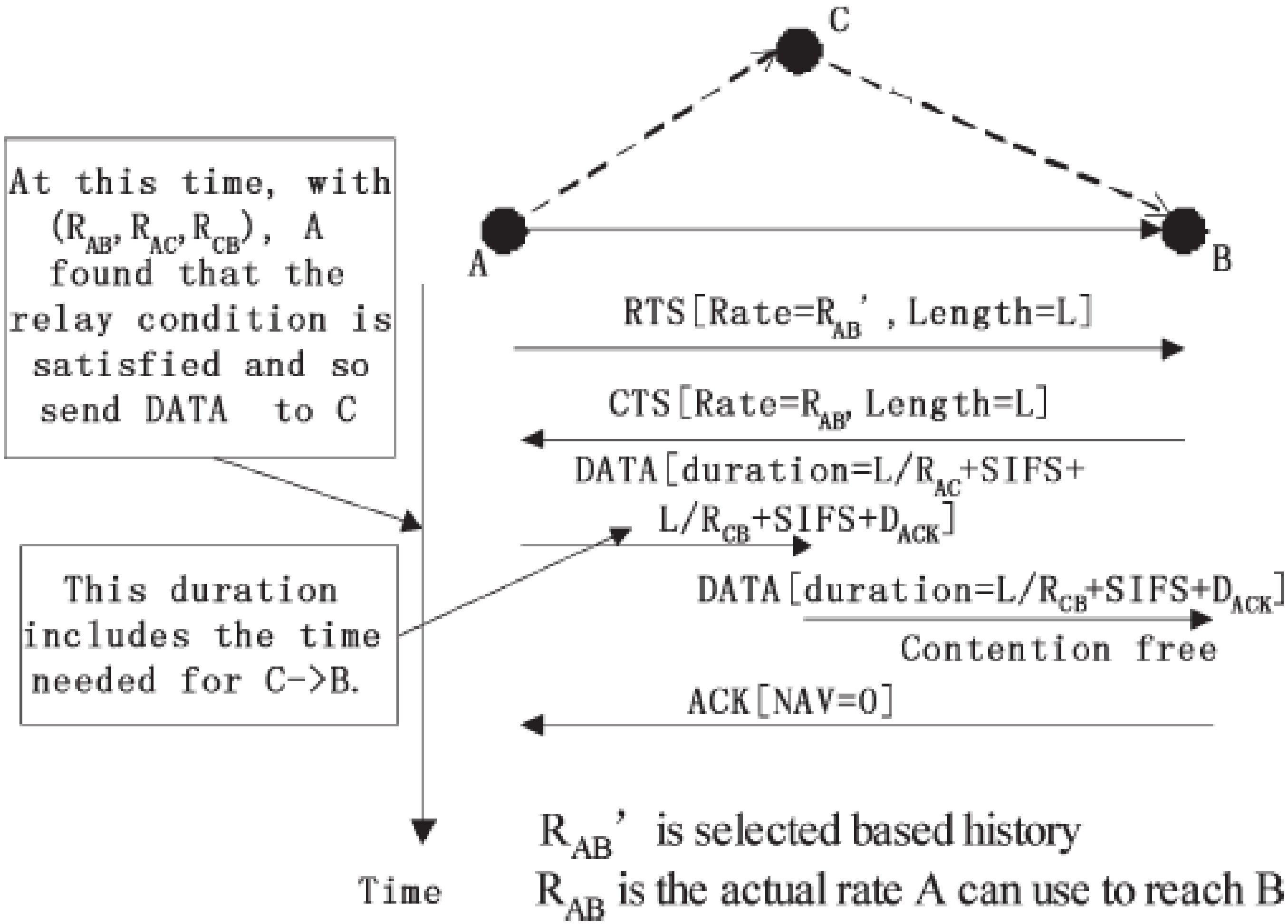
TABLE II
SERVE TABLE IN RELAY NODE

<SrcToRelay, DstToRelay>	T1	T2	BI	Rate	State

RAMA Protocol – Relay Transmission

- After exchange RTS/CTS, sender checks the Relay List to see if there is an entry corresponding to the destination
- If there is one entry for this transmission and relay condition satisfied, sender transmits data frame to relay node using relaying
- The stale entry will be flashed periodically after receiving ACK frames from receiver

RAMA Protocol – Relay Transmission



R_{AB}' is selected based history

R_{AB} is the actual rate A can use to reach B

Energy Efficiency of RAMA

- Only compare the energy consumption during data transmission
  - Energy consumed in signaling is omitted
- Total energy consumption (RAMA):

$$(P_t + P_r + P_i)t_1 + (P_t + P_r + P_i)t_2$$

- Total energy consumption (original DCF)

$$(P_t + P_r + P_i)t$$

- Because T1 + T2 < t

=> $P_{RAMA} < P_{DCF}$

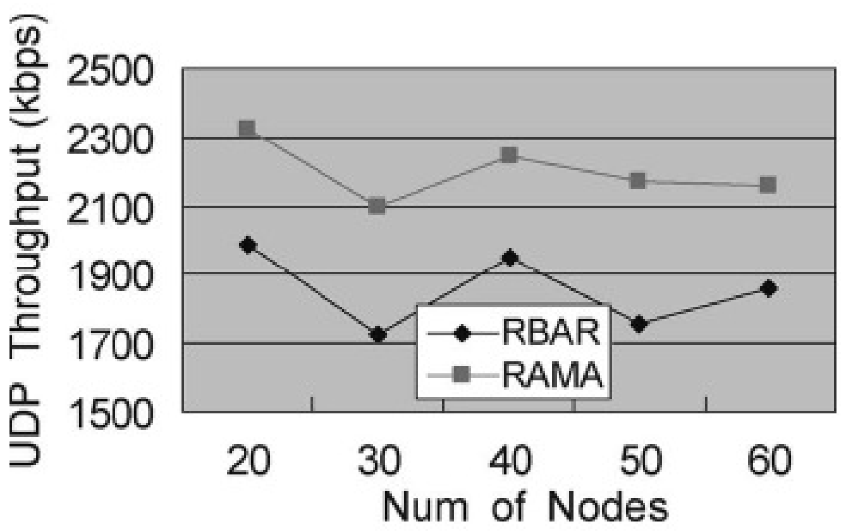
Simulation

- Using NS-2 to evaluate two protocol
  - RAMA and PBAR
- Network area is 250m x 250m
- All reported results are averaged over ten runs of 50-s simulation

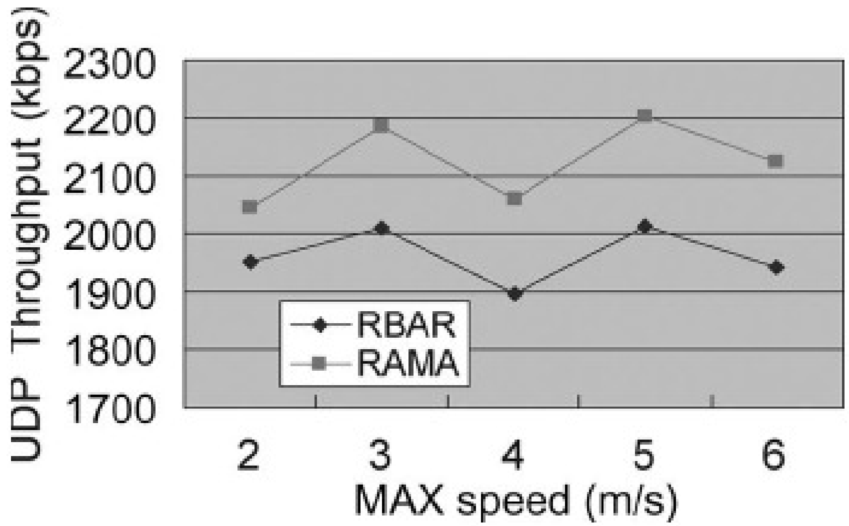
IMPORTANT PARAMETERS

Parameter	Value
Frequency	2.4GHz
Range for 11M	125m
Range for 5.5M	175m
Range for 2M	200m
Range for 1M	250m
Carrier Sensing Range	550m
INITIAL_INTERVAL	2s
MAX_INTERVAL	128s
RTS Threshold	100bytes
Packet Size	1500bytes

UDP Throughput

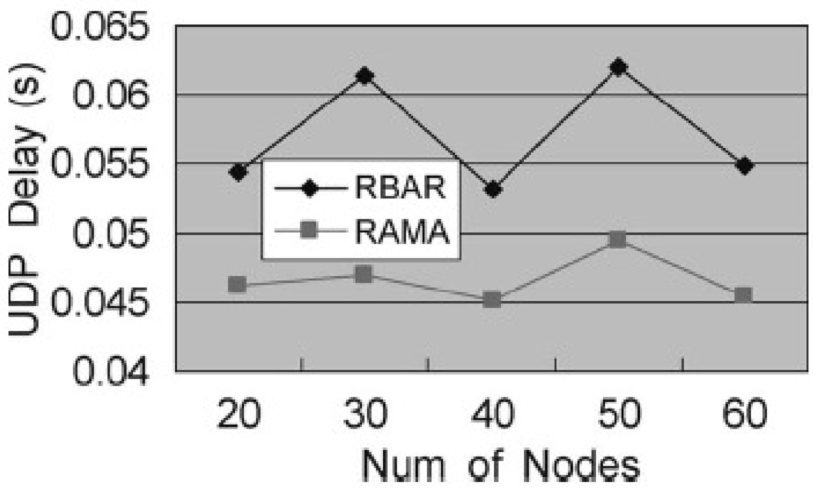


Static scenario

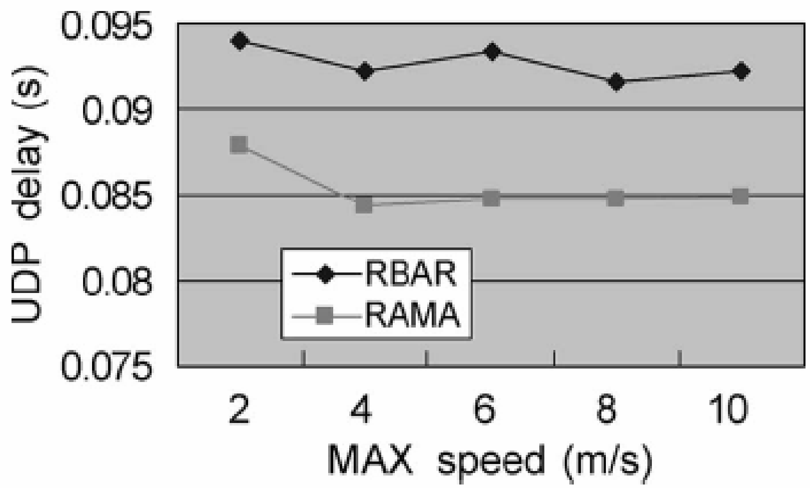


Mobile scenario

UDP Delay

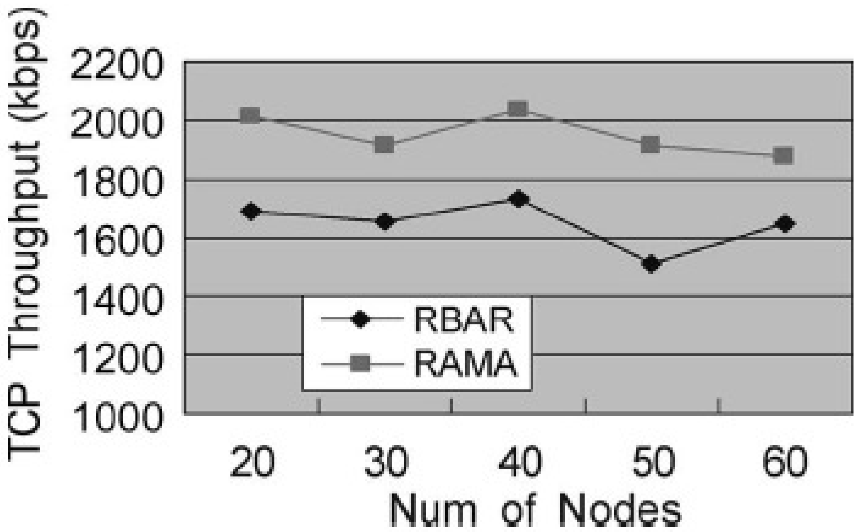


Static scenario

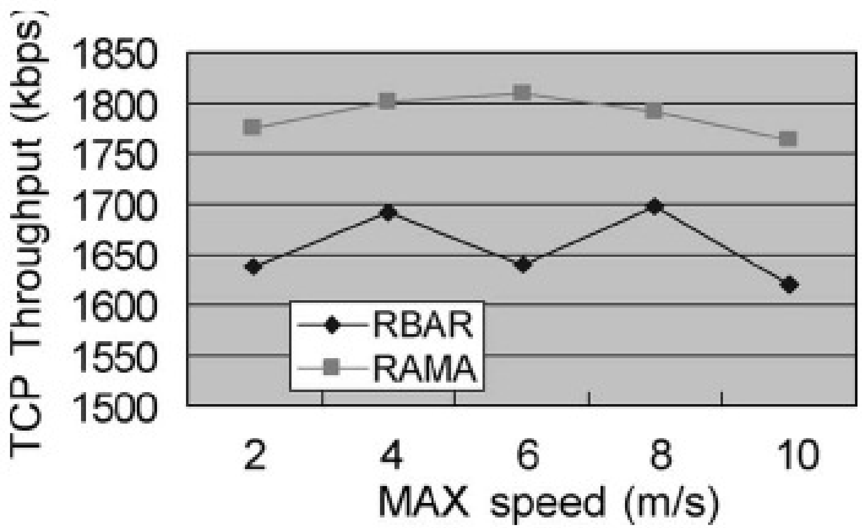


Mobile scenario

TCP Throughput

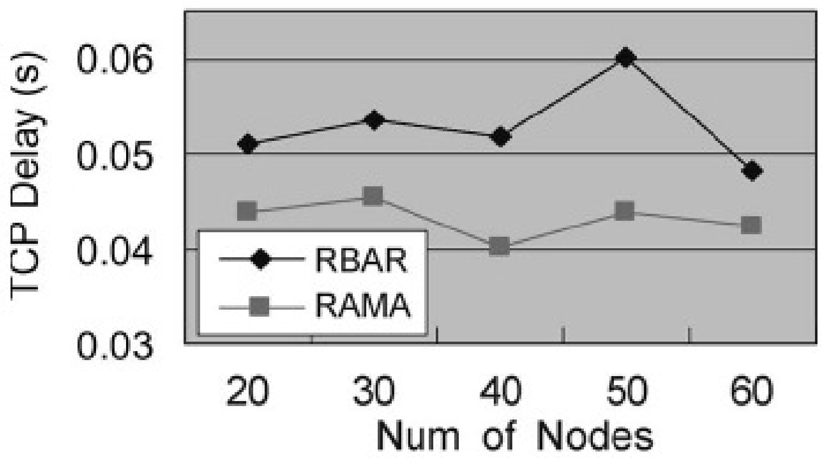


Static scenario

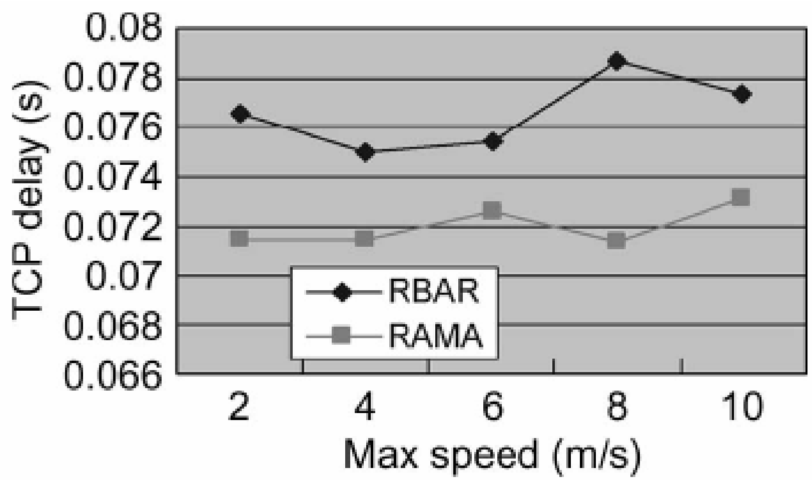


Mobile scenario

TCP Delay

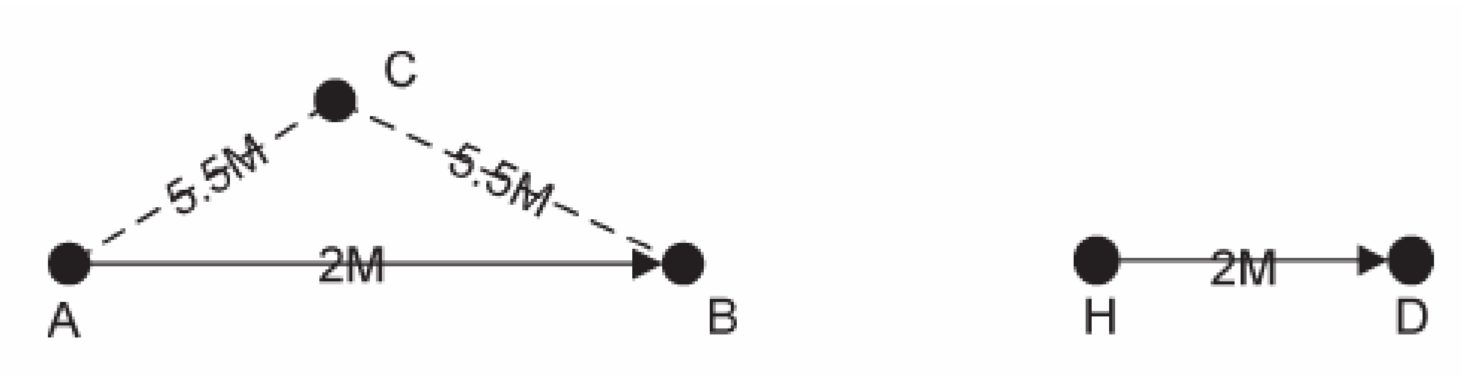


Static scenario



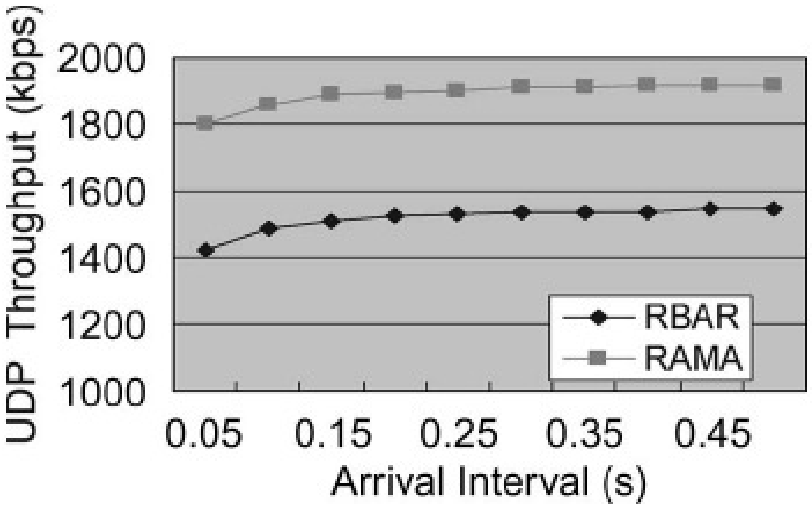
Mobile scenario

Hidden Terminal

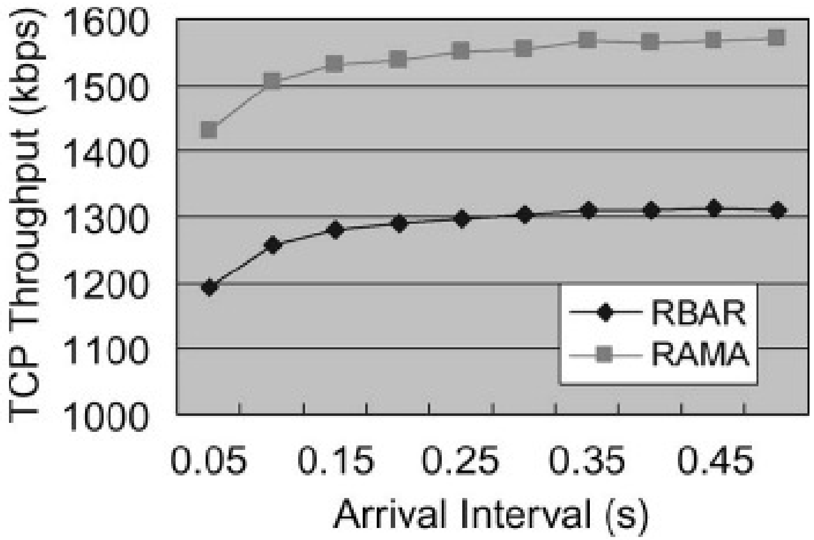


Hidden terminal scenario

Hidden Terminal

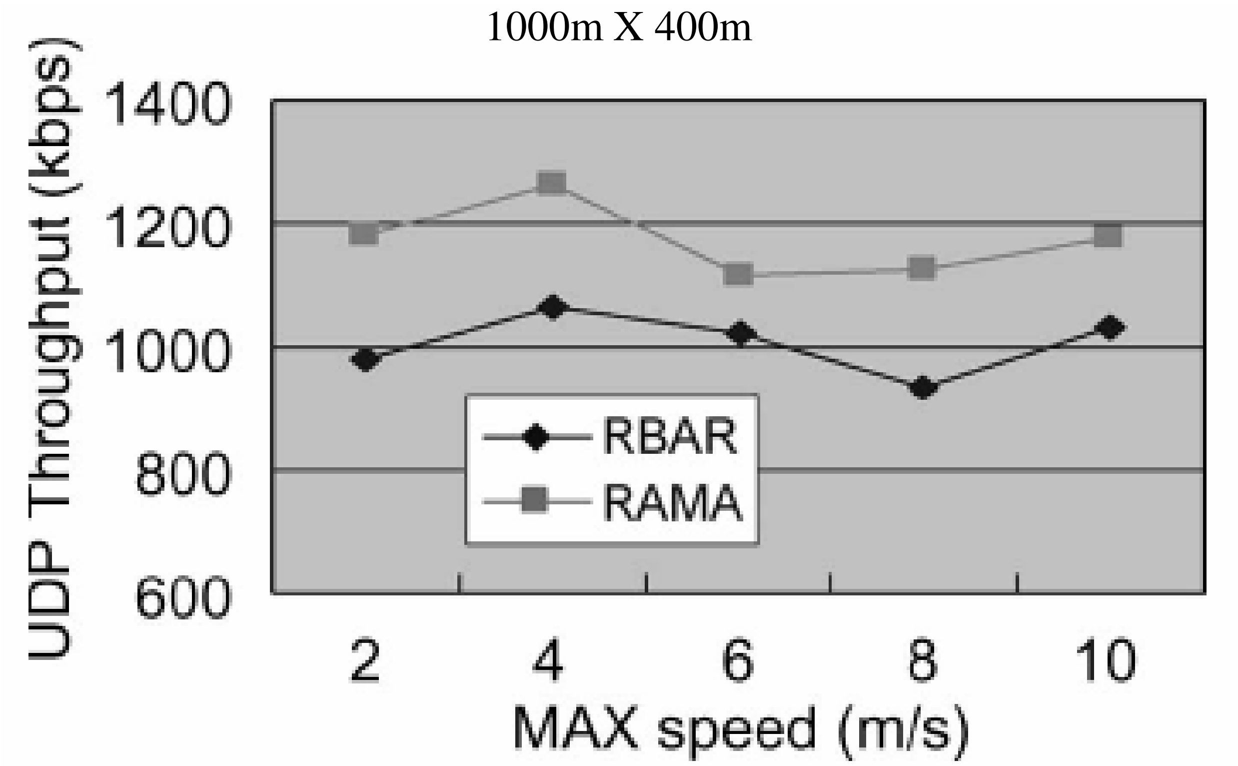


UDP Throughput with HT



TCP Throughput with HT

Multihop Scenario



UDP throughput under multihop scenario.

Conclusion

- Improvement for multihop and multirate is exploited in this paper
  - Problem definition
  - Analysis
- A RAMA protocol is developed to take the advantage of the existence of multihop high-rate links for throughput enhancement
  - Invitation Trigger
  - Relay Transmission
- Simulations show the improvement for throughput and delay in both static and mobile scenario