

A Hybrid Medium Access Control Protocol for Underwater Wireless Networks

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September 14, 2007
WUWNet 2007

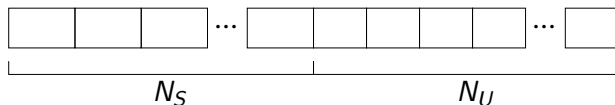
Introduction

- ▶ Underwater networks provide many challenges
 - ▶ Low signal propagation speed
 - ▶ Low data rates
 - ▶ Limited energy resources
- ▶ MAC protocols play important role in conserving energy
 - ▶ Controls when transceiver is operational
 - ▶ Transceiver consumes large amounts of energy

Introduction

- ▶ Problem
 - ▶ TDMA protocols achieve low efficiency with few active nodes and can not adapt to traffic conditions
 - ▶ Random protocols achieve low efficiency with many active nodes through collisions
- ▶ Proposed Solution
 - ▶ Divide each frame into portions reserved for scheduled and unscheduled access
 - ▶ Share state information during scheduled access to improve use of unscheduled slots

Hybrid MAC Protocol



- ▶ Divide frame into N_S scheduled and N_U unscheduled slots
- ▶ Share state information during scheduled slots
- ▶ Adjust unscheduled access based on state information

Analysis Introduction

- ▶ For an initial analysis, assume:
 - ▶ $N = 10$ nodes surrounding a central receiver
 - ▶ T nodes are backlogged with many packets
 - ▶ Packets are lost only through collision
- ▶ Define the following
 - ▶ E_{TX} : Average energy to transmit a packet in a slot
 - ▶ E_{RX} : Average energy to receive a packet in a slot
 - ▶ E_I : Energy to remain idle in a slot

Protocol Energy Equations

- ▶ TDMA

$$E_T = \frac{TE_{TX} + (N - 1)TE_{RX} + N(N_S - T)E_I}{N_S}$$

- ▶ Unscheduled

$$E_U = \frac{P_R N_U E_{TX} + (N - 1)P_R N_U E_{RX} + N(1 - P_R)N_U E_I}{N_U}$$

- ▶ P_R is the probability of a successful reception in a slot

- ▶ Hybrid

$$E_H = \frac{E_T N_S + E_U N_U}{N_S + N_U}$$

Protocol Efficiency Equations

- ▶ TDMA

$$\mathcal{E}_T = \frac{T}{E_T N_S}$$

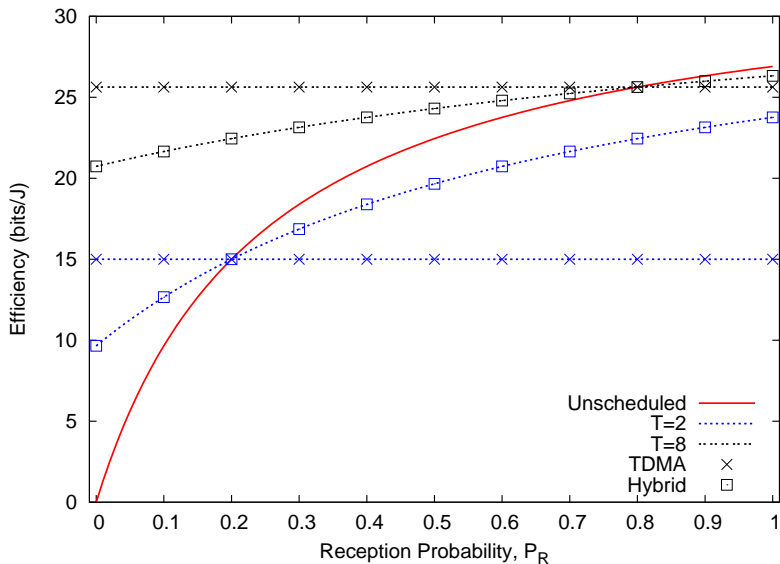
- ▶ Unscheduled

$$\mathcal{E}_U = \frac{P_R N_U}{E_U N_U}$$

- ▶ Hybrid

$$\mathcal{E}_H = \frac{(T + P_R N_U)}{E_T N_S + E_U N_U}$$

Abstract Protocol Efficiency



Concrete Random Protocol

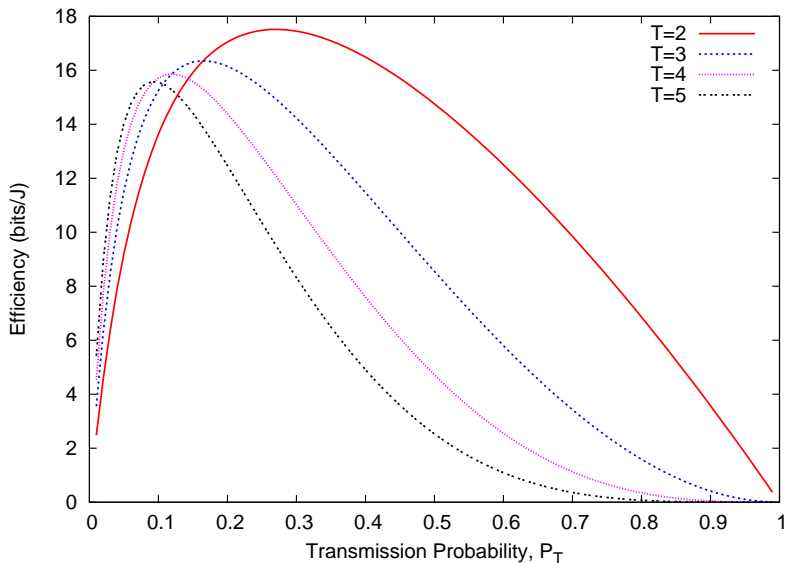
- ▶ Random Protocol
 - ▶ Similar to Slotted Aloha
 - ▶ Packets are only backlogged
 - ▶ P_T is the probability of transmitting in a slot
- ▶ Efficiency

$$\mathcal{E} = \frac{B(1, T, P_T)}{B(0, T, P_T)NE_I + \overline{E}_1}$$

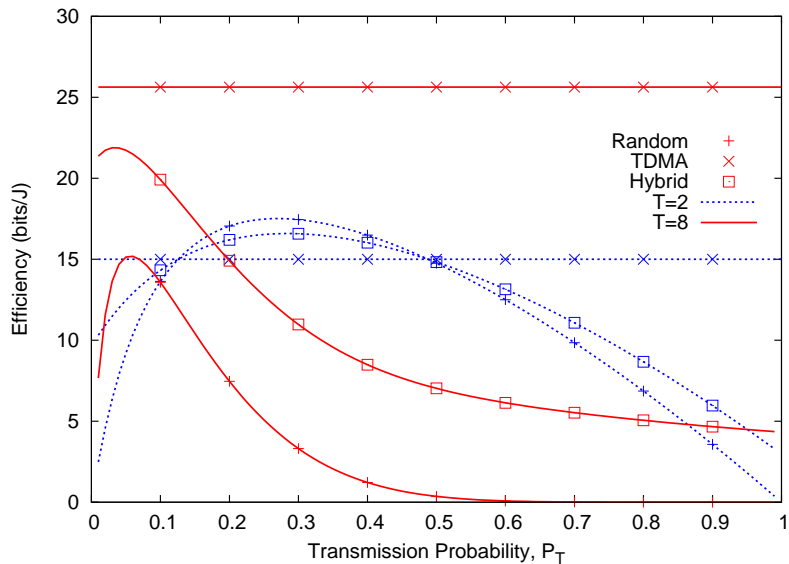
where

$$\overline{E}_1 = \sum_{i=1}^T B(i, T, P_T)(iE_{TX} + (N - i)E_{RX})$$

Concrete Random Protocol Efficiency



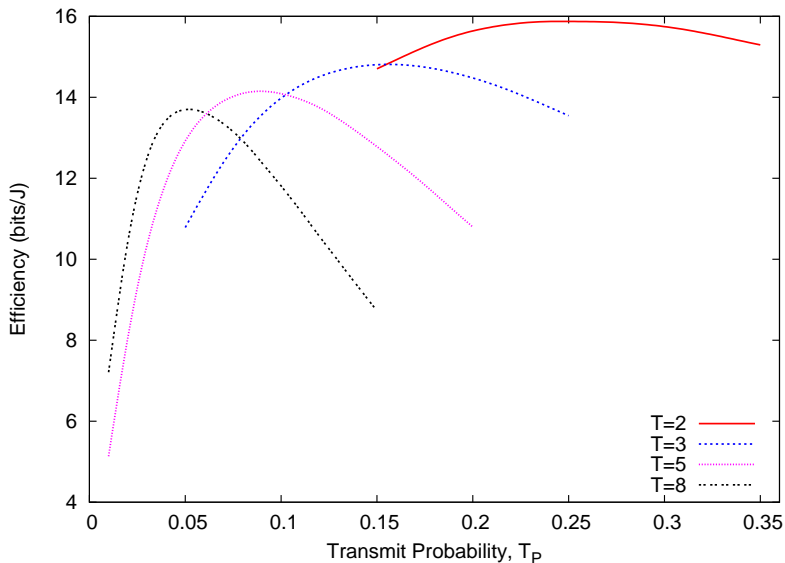
Protocol Efficiency



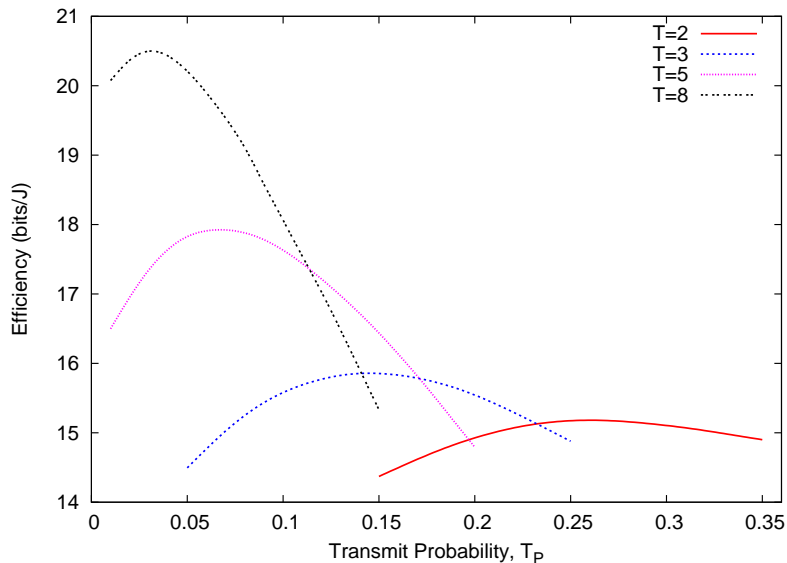
Simulation Introduction

- ▶ Device models
 - ▶ Ten devices in a circle around a central receiver
 - ▶ Underwater channel with practical spreading ($\alpha = 1.5$)
 - ▶ BPSK bit error model
 - ▶ 40 W P_{TX} , 3 W P_{RX} , 80 mW P_I
- ▶ Protocols
 - ▶ TDMA
 - ▶ Random – modified Slotted Aloha
 - ▶ Hybrid – combination of TDMA and Random
 - ▶ Aware Hybrid – nodes share transmission desire and nodes adjust transmit probability
 - ▶ Divider – nodes share packet queue length and divide unscheduled slots proportionally

Random Protocol Efficiency



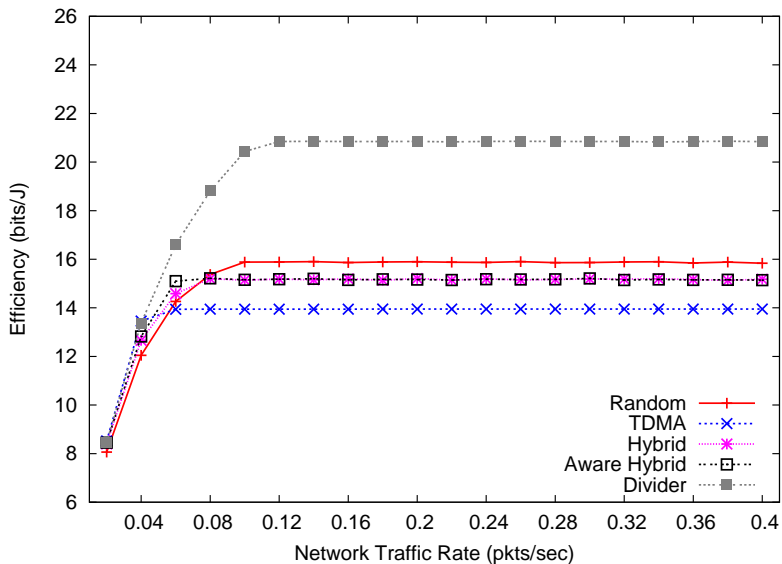
Hybrid Protocol Efficiency



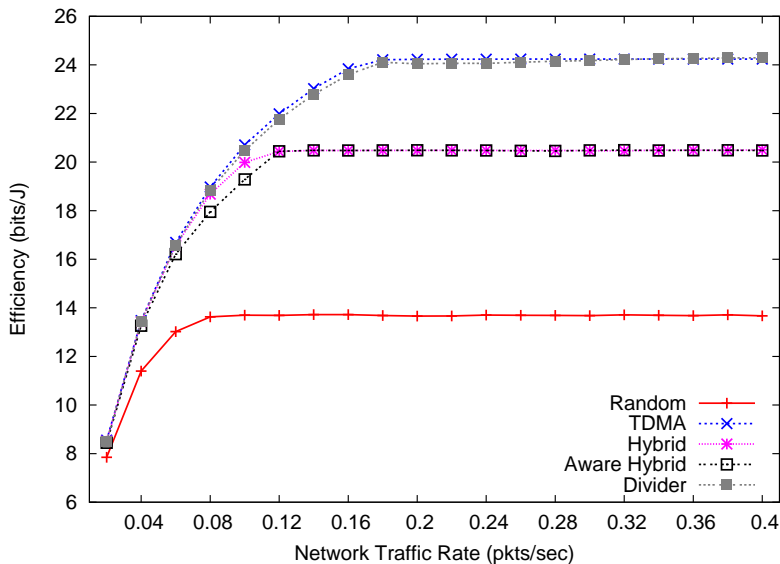
Optimal Transmit Probability

T	Random	Hybrid
2	0.25	0.26
3	0.155	0.145
4	0.11	0.095
5	0.09	0.065
6	0.07	0.05
7	0.06	0.04
8	0.05	0.03
9	0.045	0.025
10	0.04	0.02

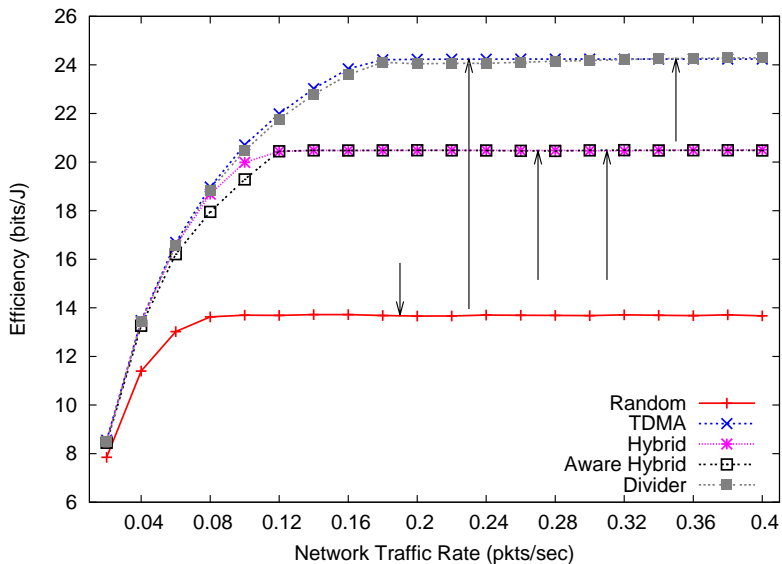
Protocol Efficiency for $T = 2$



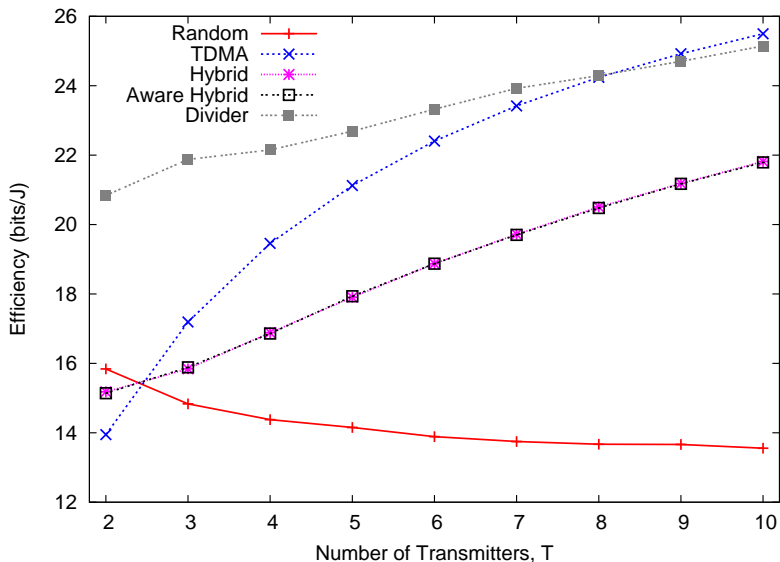
Protocol Efficiency for $T = 8$



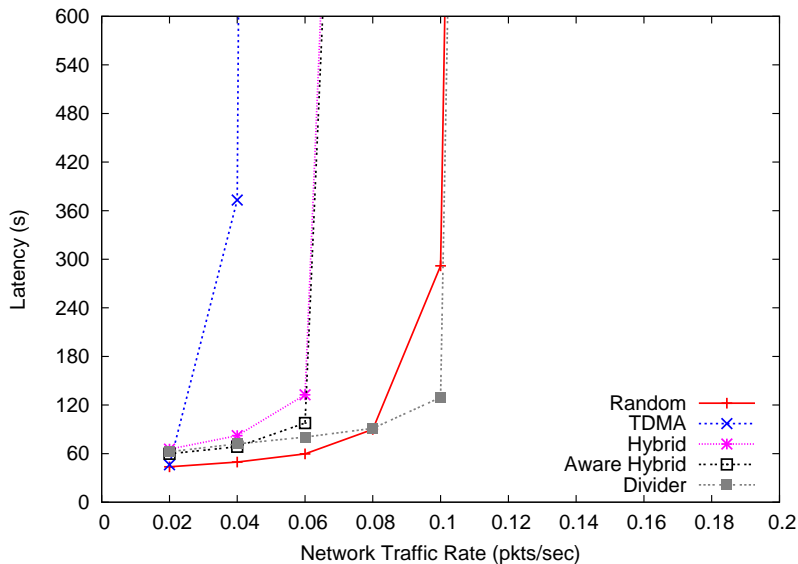
Protocol Efficiency for $T = 8$



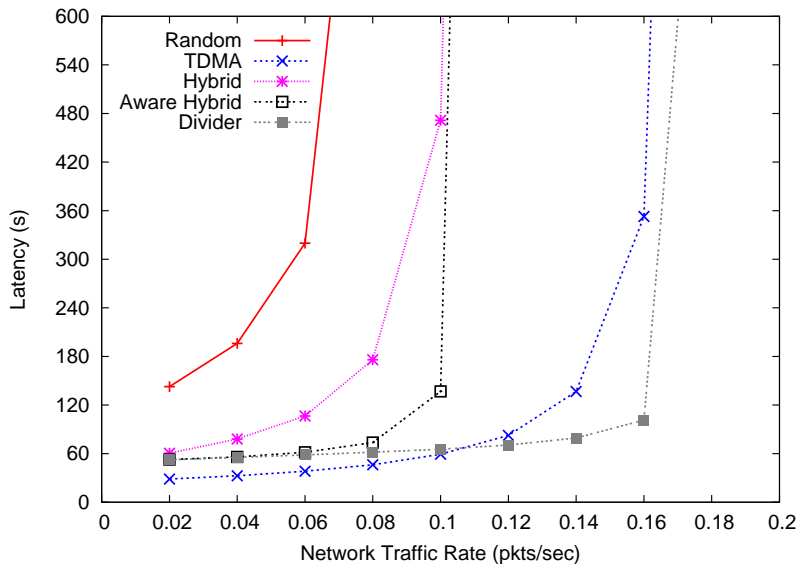
Protocol Efficiency as T Varies



Message Latency for $T = 2$

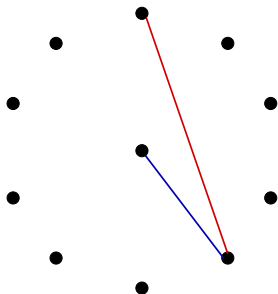


Message Latency for $T = 8$

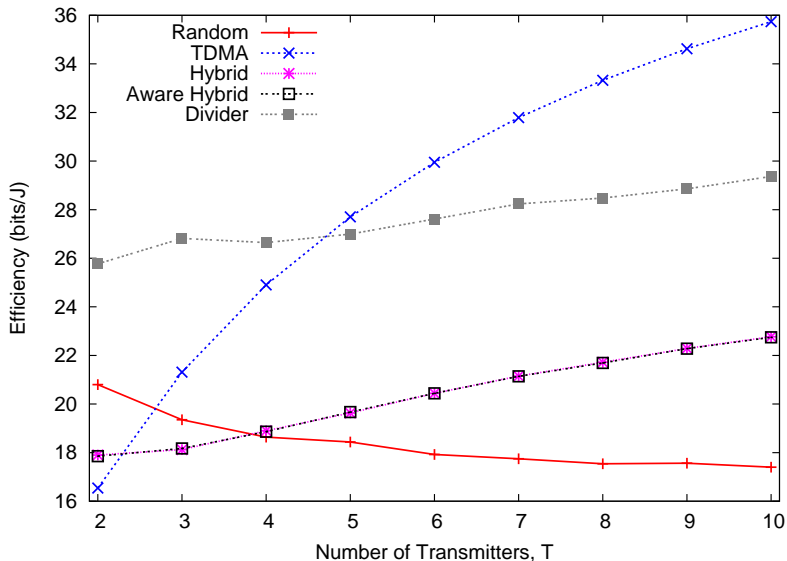


Low Power Protocol

- ▶ Stateful protocols require a higher transmit power than TDMA
- ▶ Allow nodes to adjust transmit power
 - ▶ Transmit packets to central receiver at low power (15 W)
 - ▶ Transmit packets with state information at high power (40 W)

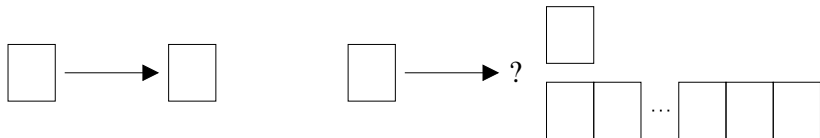


Low Power Protocol Efficiency

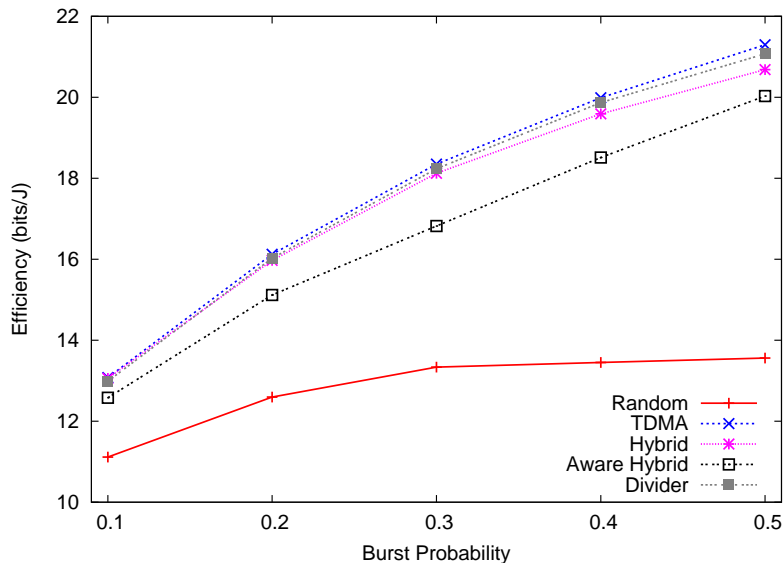


Bursty Traffic

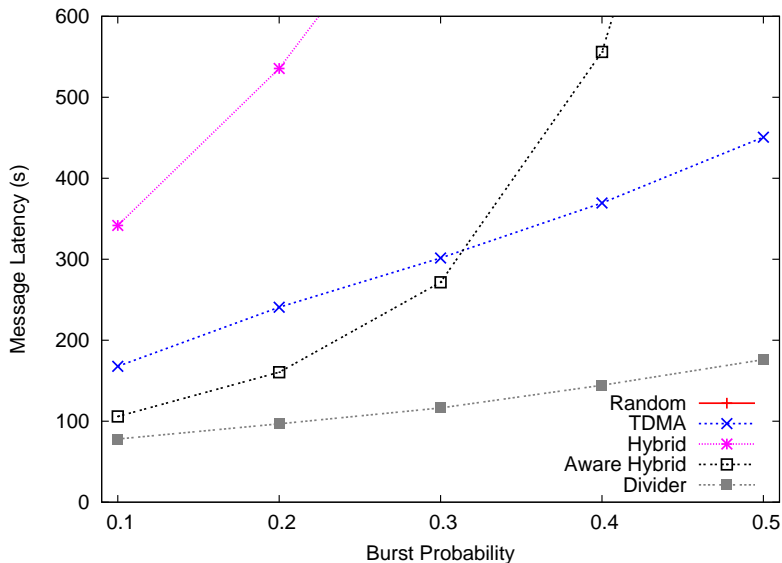
- ▶ Hybrid protocols may adapt to changing traffic conditions
- ▶ Simulate a variable traffic load
 - ▶ All nodes transmit ($T = 10$)
 - ▶ Nominal rate of 0.02 packets/sec
 - ▶ Nodes randomly produce either 10 packets or one packet



Protocol Efficiency for Bursty Traffic



Protocol Latency for Bursty Traffic



Conclusions

- ▶ A Hybrid MAC may provide better performance
 - ▶ A higher efficiency except for heavily loaded networks with many transmitters
 - ▶ A lower and more consistent delay for a wider range of rates
 - ▶ Adaptability to bursts in generated traffic
- ▶ State information must be used judiciously
 - ▶ The Aware Hybrid protocol did not perform better than the Hybrid protocol in most cases
 - ▶ The Divider protocol performed very well

Thank You!

Questions?

Protocol Energy

