EM-MAC: A Dynamic Multichannel Energy-Efficient MAC Protocol for Wireless Sensor Networks

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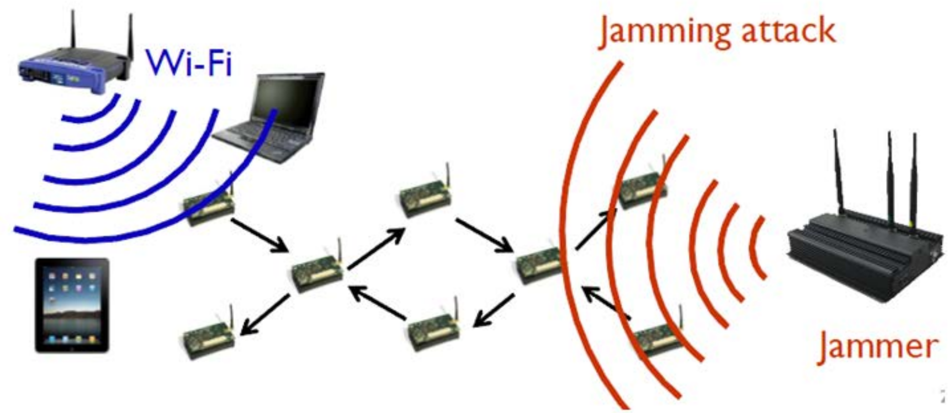
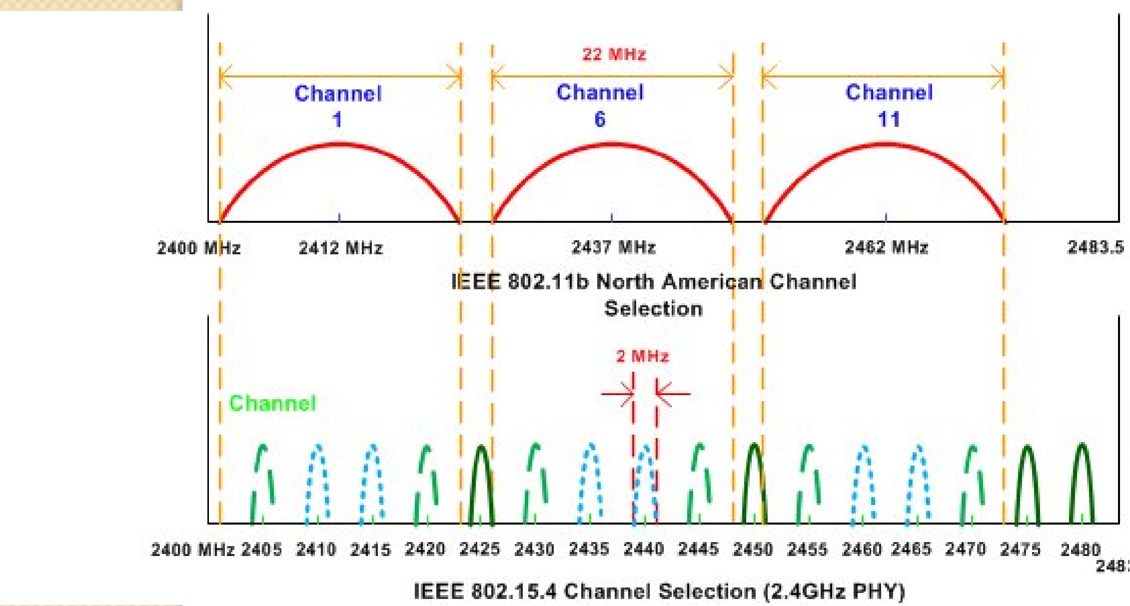
Introduction

Single Channel:

Interference,
Jamming attack

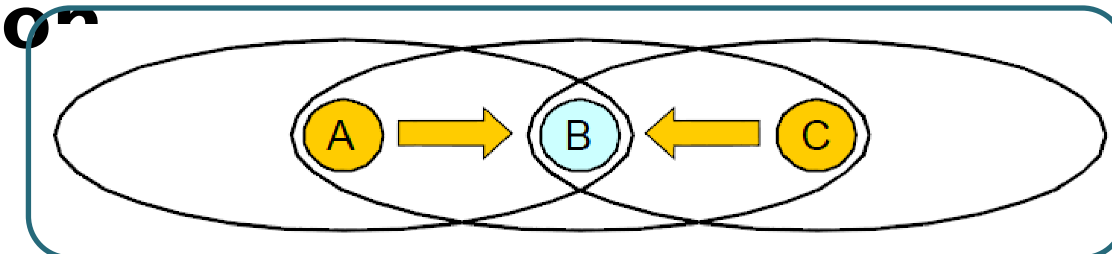


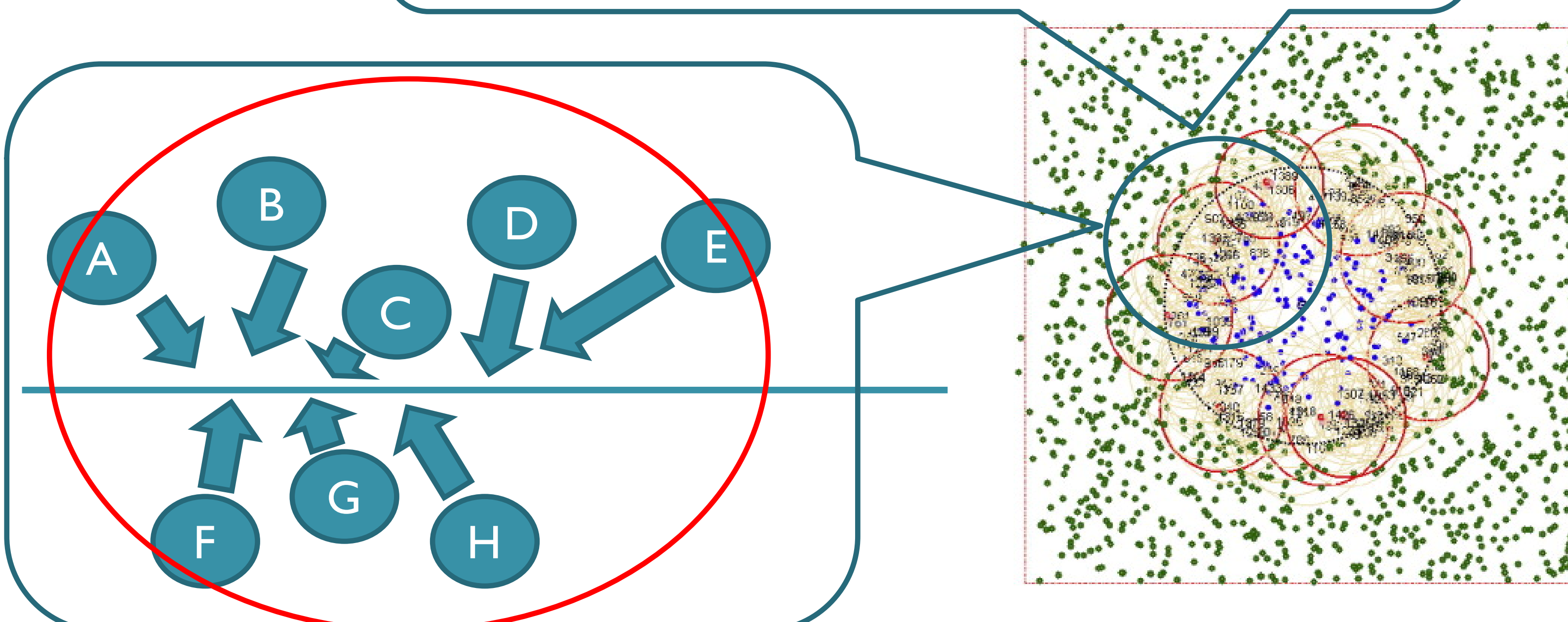


Introduction

Single Channel:

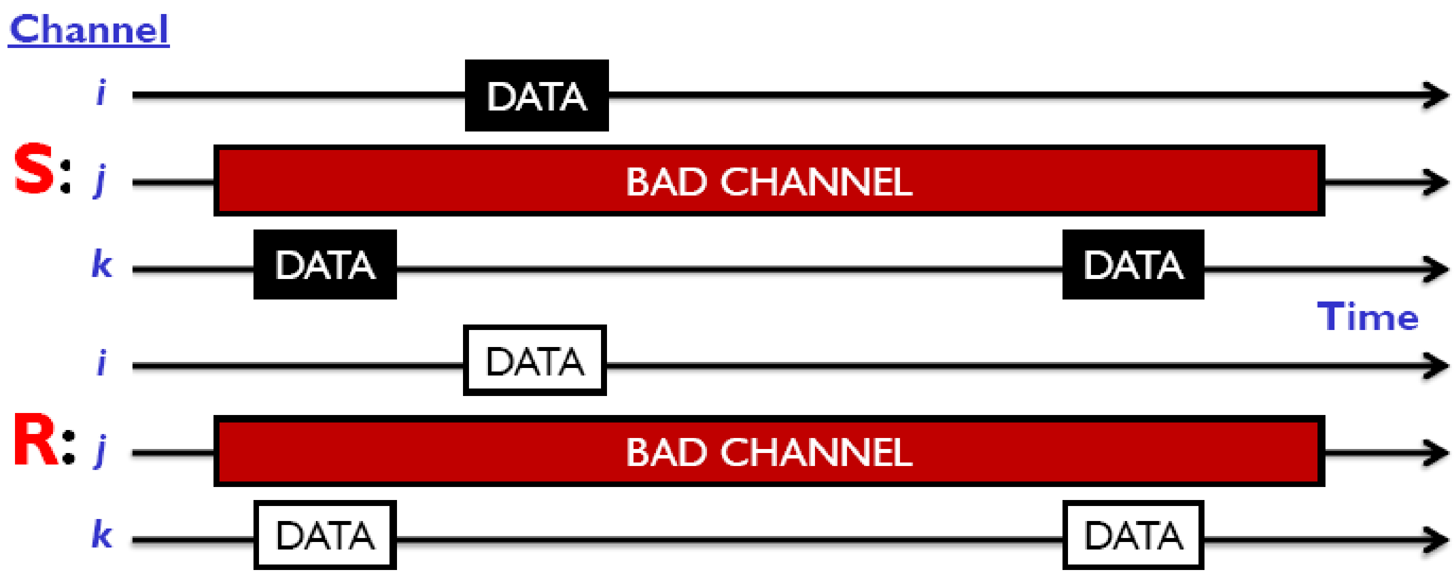
Hidden terminals & Heavy wireless usage in one location





Channel, *i*

EM-MAC Objectives



- Spread traffic to multiple channels - reduce collisions.
- Efficiently deliver packets under interference (e.g. Wi-Fi) or even under jamming attack.

High energy efficiency Multi-Channel MAC

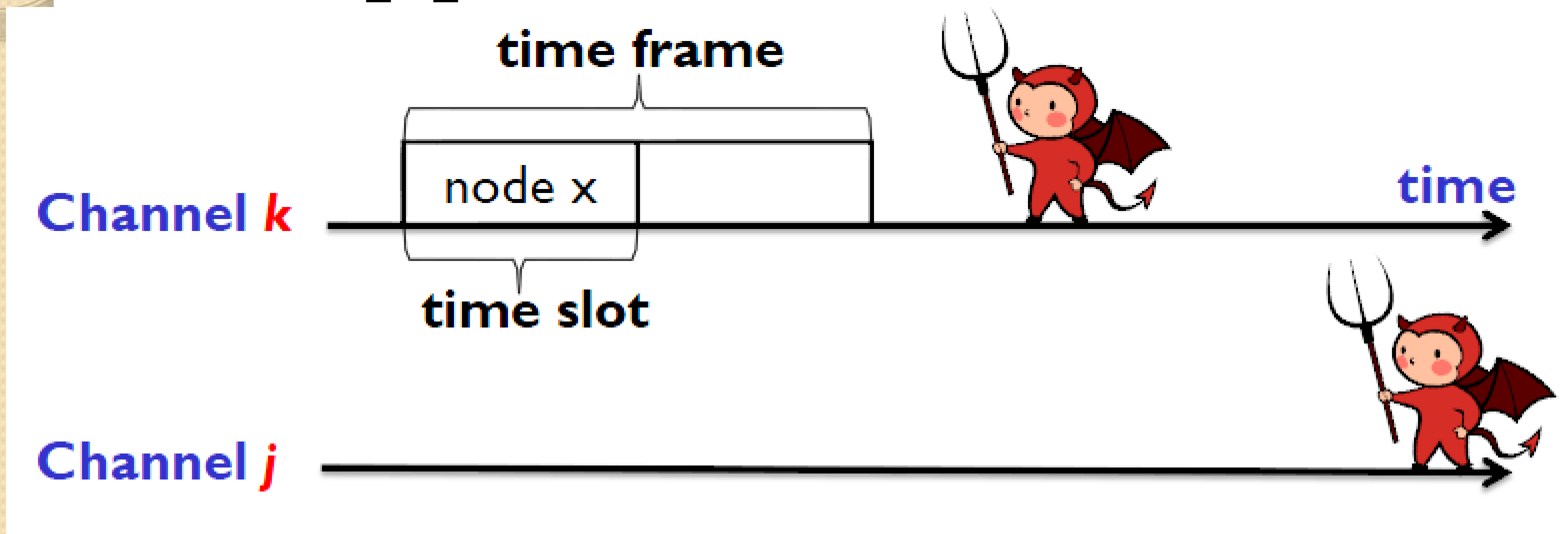
Related Works

- **Single Channel Energy efficient**: S-MAC [25], B-MAC [13], X-MAC [3], DW-MAC [20], RI-MAC [21], and PW-MAC [22].
- **Multi-Channel ad-hoc MAC**: SSCH [1] and McMAC [17].
- **Multi-Chan... Network MAC**: ... [5], MMAC [18], and ...].

Required Common
Control Channel

Related Works

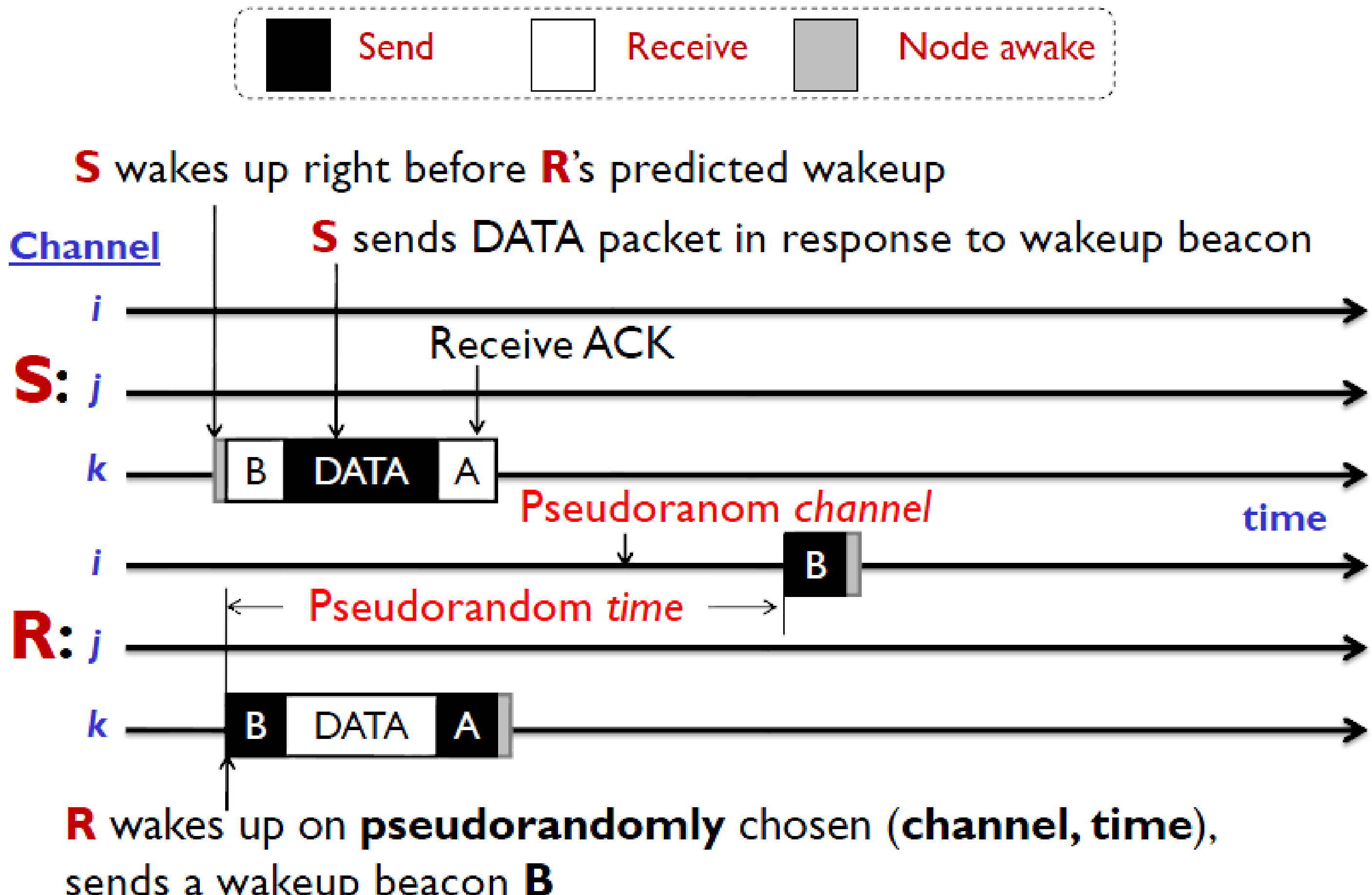
McChMAC [2]



- **Downsides:**
  1. Requires global time synchronization.
  2. Utilize a fixed set of channels.
  3. Inefficient handling dynamic traffic.

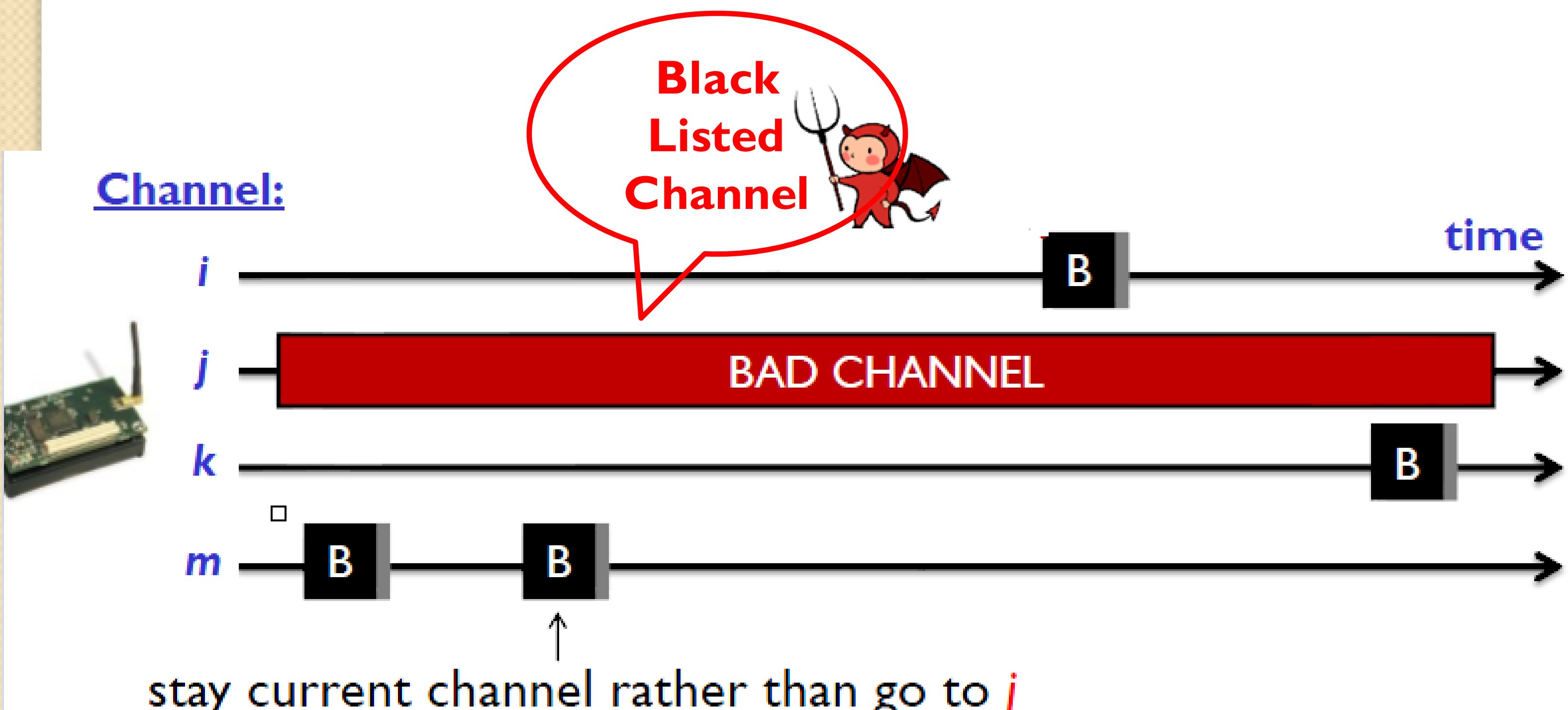
EM-MAC Overview

Dynamic Multichannel Energy-Efficient MAC Protocol for Wireless Sensor Networks



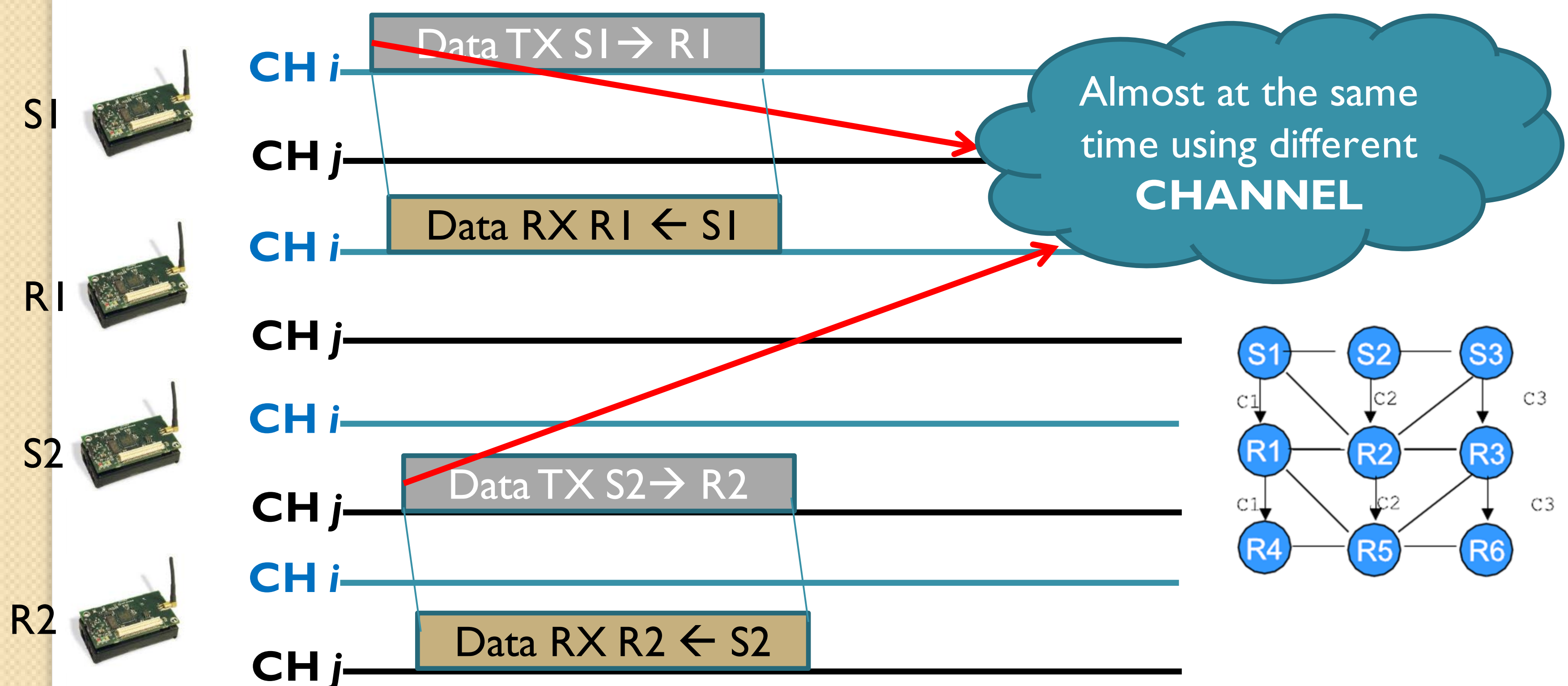
EM-MAC Features

1) Dynamically select channels: Robust against interference and jamming attacks



EM-MAC Features

2) Spread traffic to different channels and times: lower contention, higher network throughput.

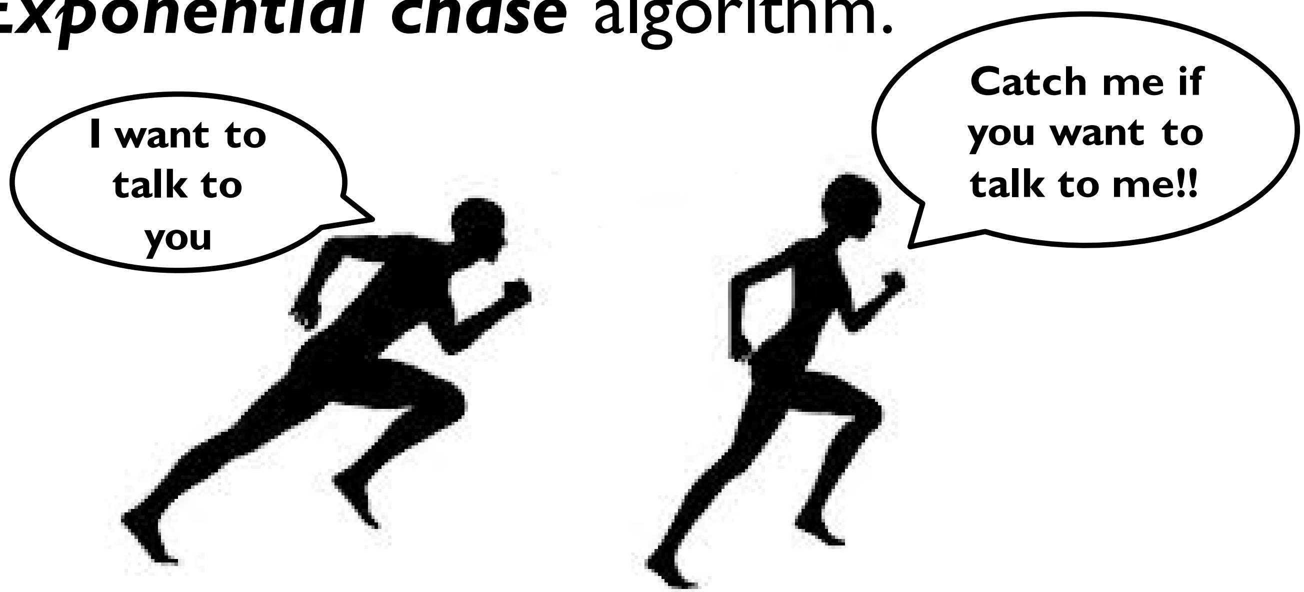


EM-MAC Features

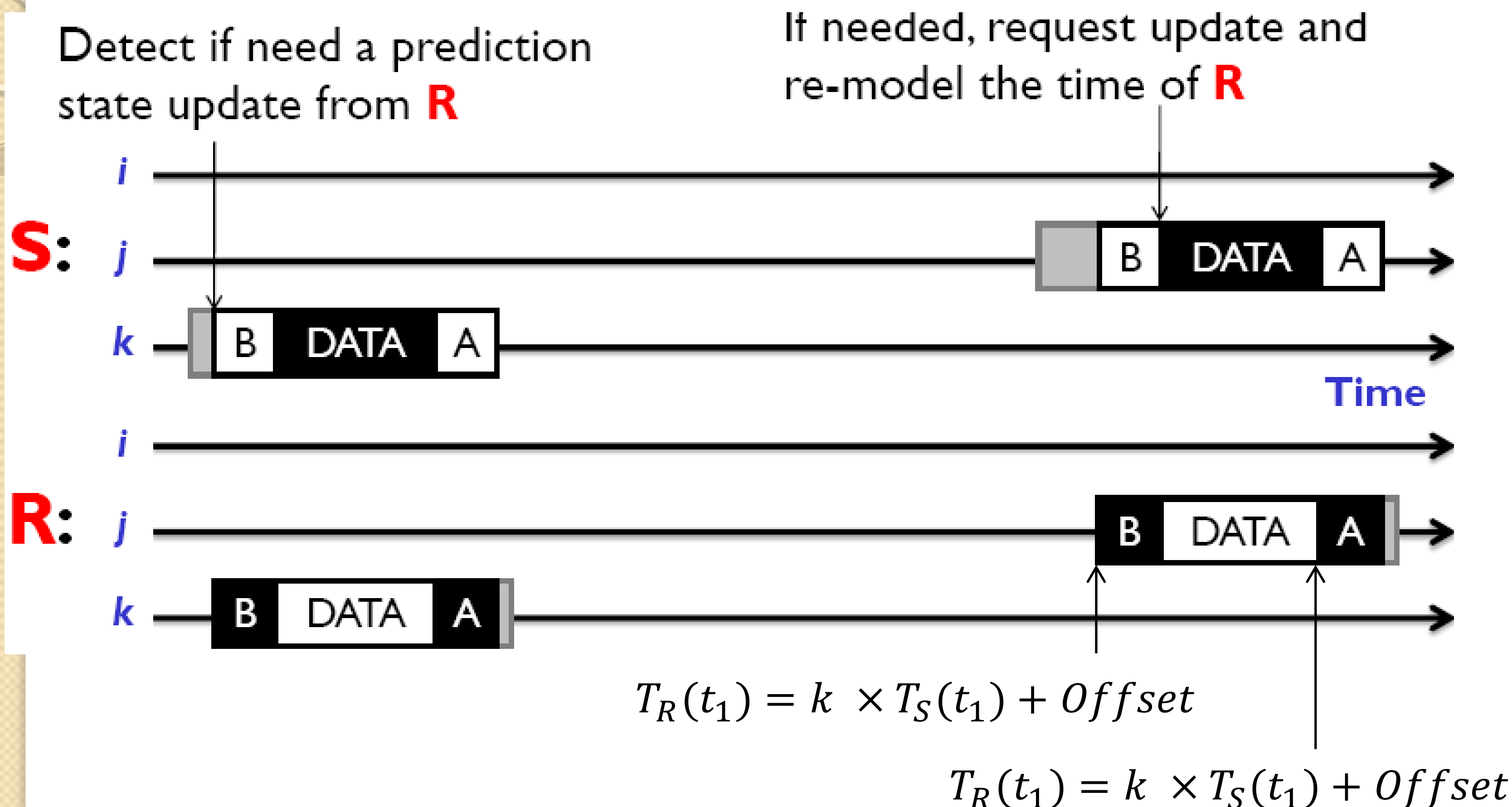
3) Sender predicts receiver (channels and times): with high energy efficiency method.

a) Adaptive receiver time modeling technique, and

b) Exponential chase algorithm.



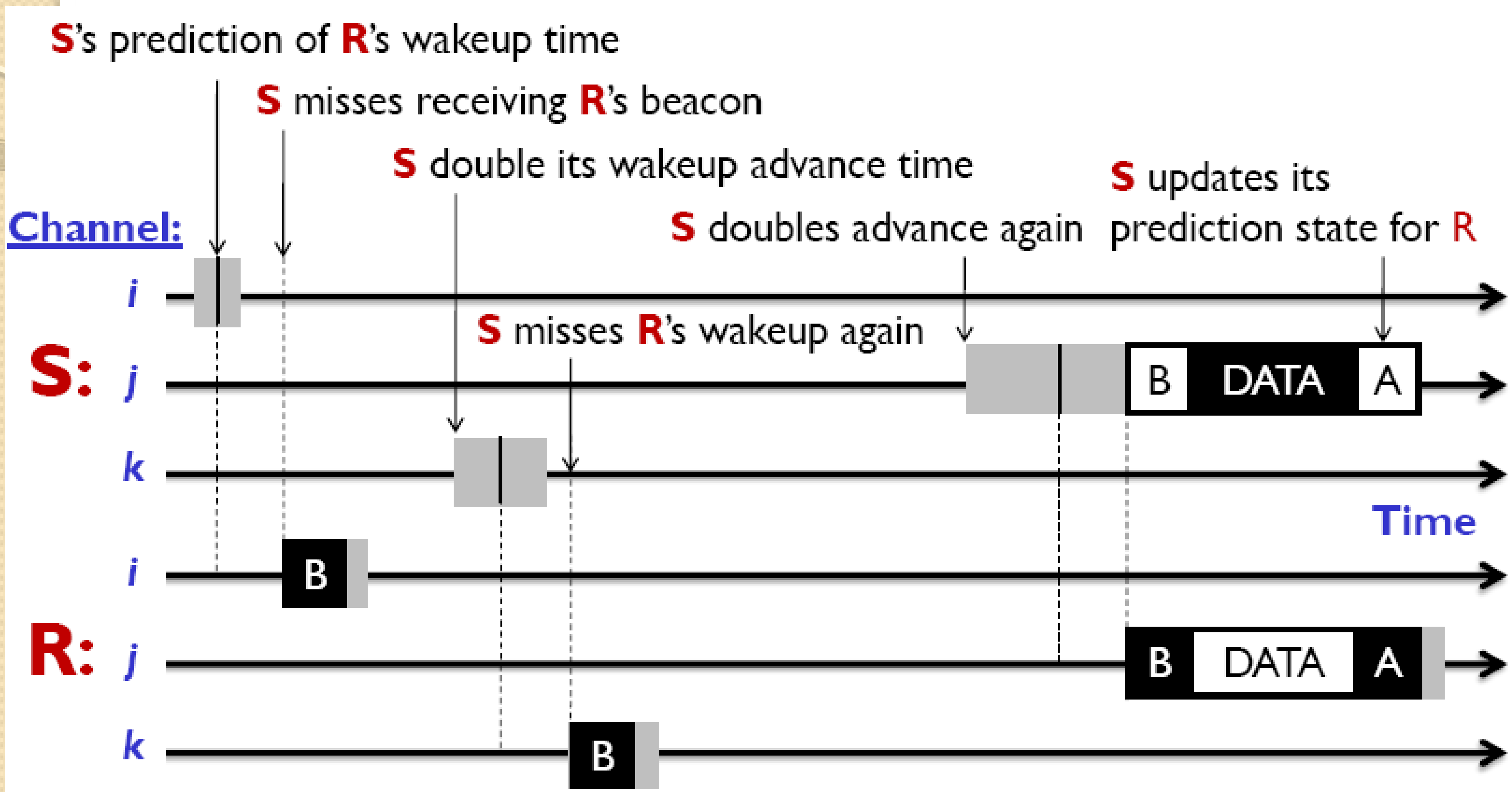
Adaptive Time Modeling



S adaptively models the time of R:

$$T_R(t) = k \times T_S(t) + Offset$$

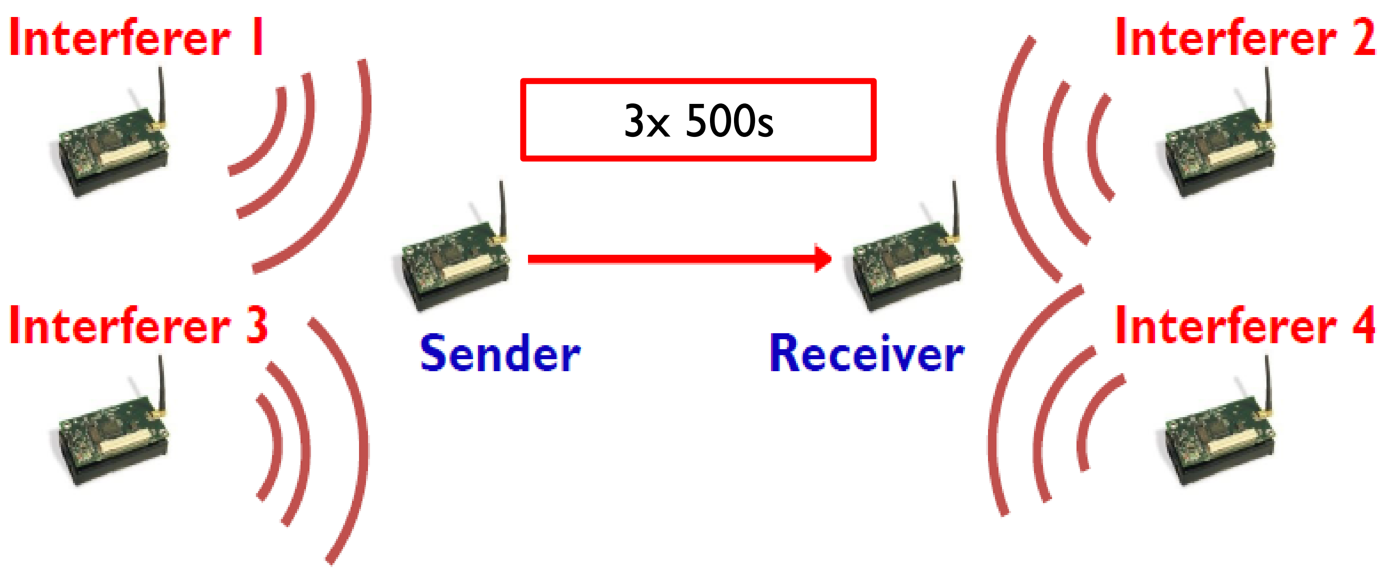
Exponential Chase Algorithm



Quickly re-rendezvousing back with receiver is crucial to maintaining a **small sender duty cycle** and **packet delivery latency**

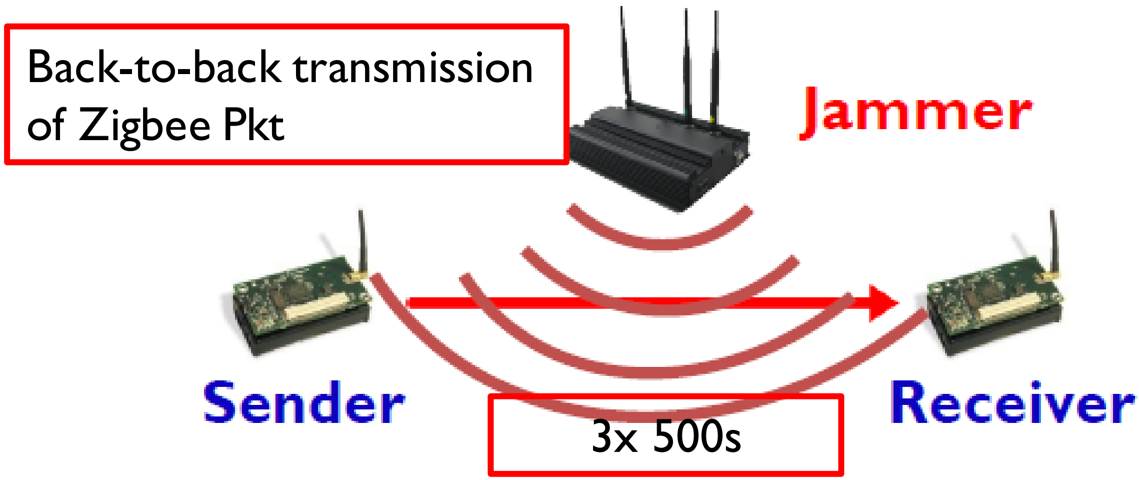
Performance under ZigBee Interference

Pkt = 100byte
Periodic = 20ms
No CCA used



Protocol	ZigBee Interference		
	Sender Duty Cycle	Delivery Latency (ms)	PDR
EM-MAC	6.3%	625	100.0%
Y-MAC	25.8%	57283	100.0%
PW-MAC	39.2%	1506	100.0%

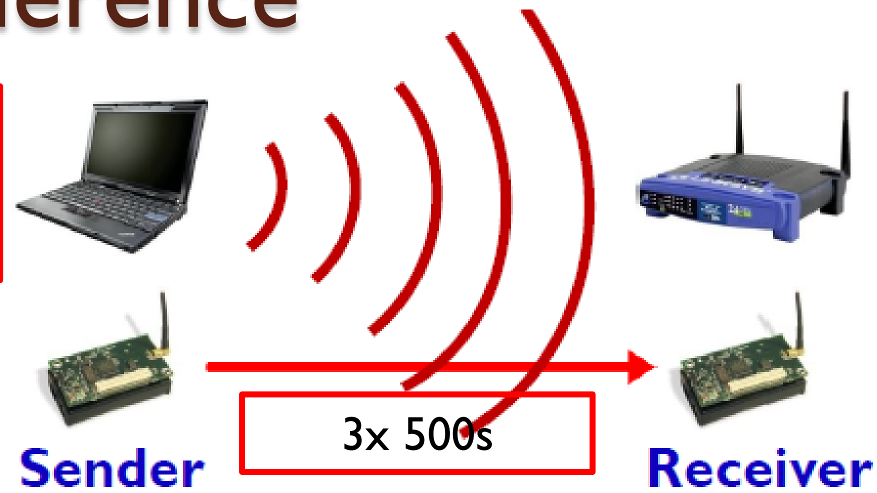
Performance under ZigBee Jamming



Protocol	ZigBee Jamming		
	Sender Duty Cycle	Delivery Latency (ms)	PDR
EM-MAC	6.4%	675	100.0%
Y-MAC	100.0%	∞	0.0%
PW-MAC	100.0%	∞	0.0%

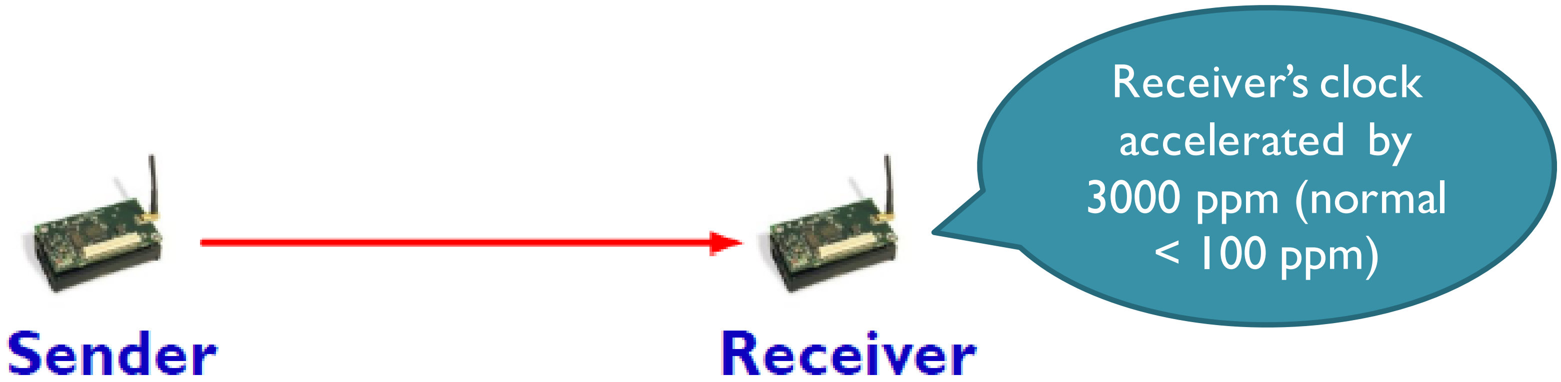
Performance under Wi-Fi Interference

TCP
3,6Mbps
WiFi CH = WSN CH



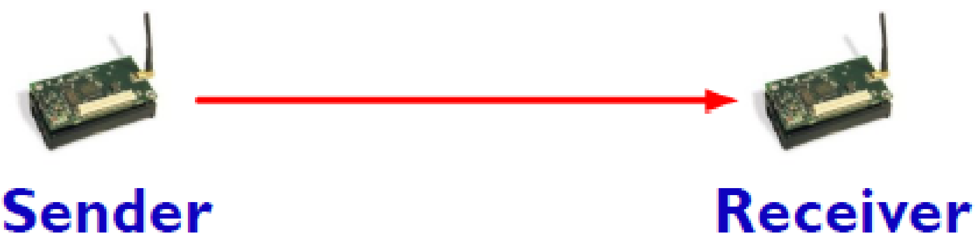
Protocol	Wi-Fi Interference		
	Sender Duty Cycle	Delivery Latency (ms)	PDR
EM-MAC	6.4%	670	100.0%
Y-MAC	91.0%	252506	35.2%
PW-MAC	76.0%	309197	12.0%

Performance under large clock rate difference



Protocol	Sender Duty Cycle	Delivery Latency (ms)	PDR
EM-MAC	5.3%	611	100.0%
Y-MAC	32.8%	5130	100.0%
PW-MAC	19.8%	762	100.0%

Performance under different rendezvous methods

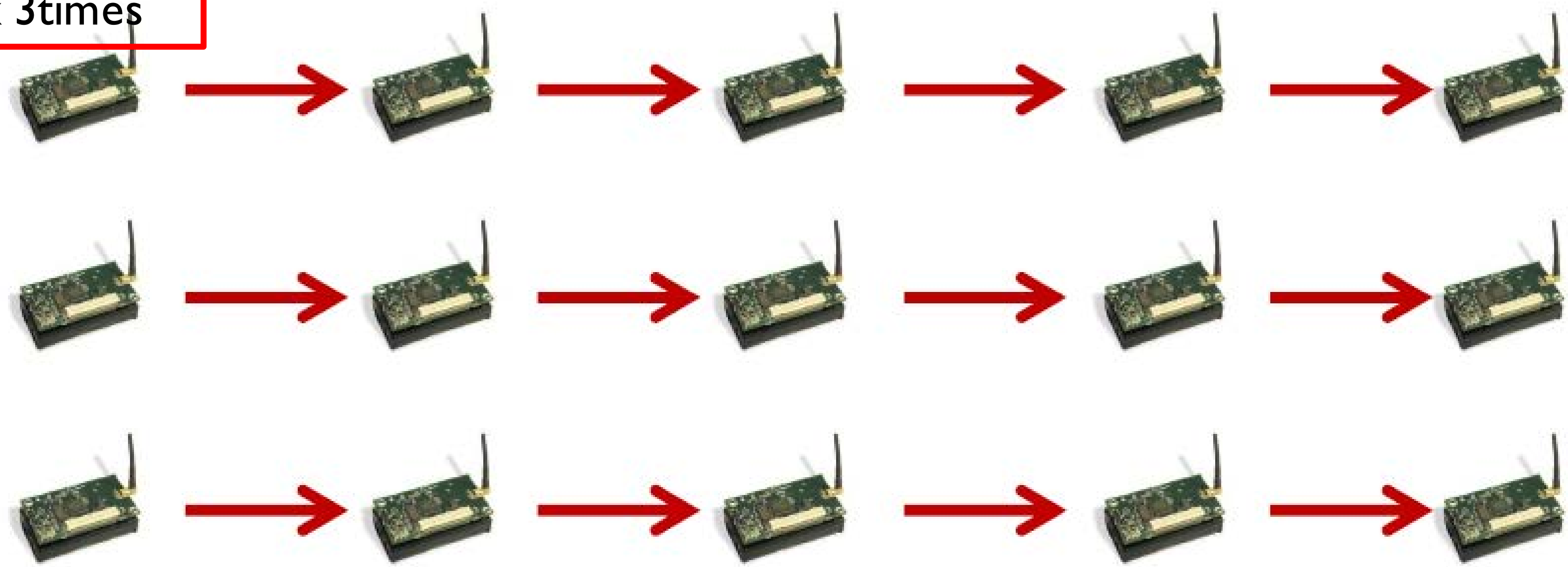


Rendezvous Method	Rendezvous Latency (ms)	Sender Duty Cycle
EM-MAC Exponential Chase	902	6.7%
Waiting-at-one-channel	9095	100.0%
Rotating-different-channel	8153	100.0%

Switch Ch. every 1s

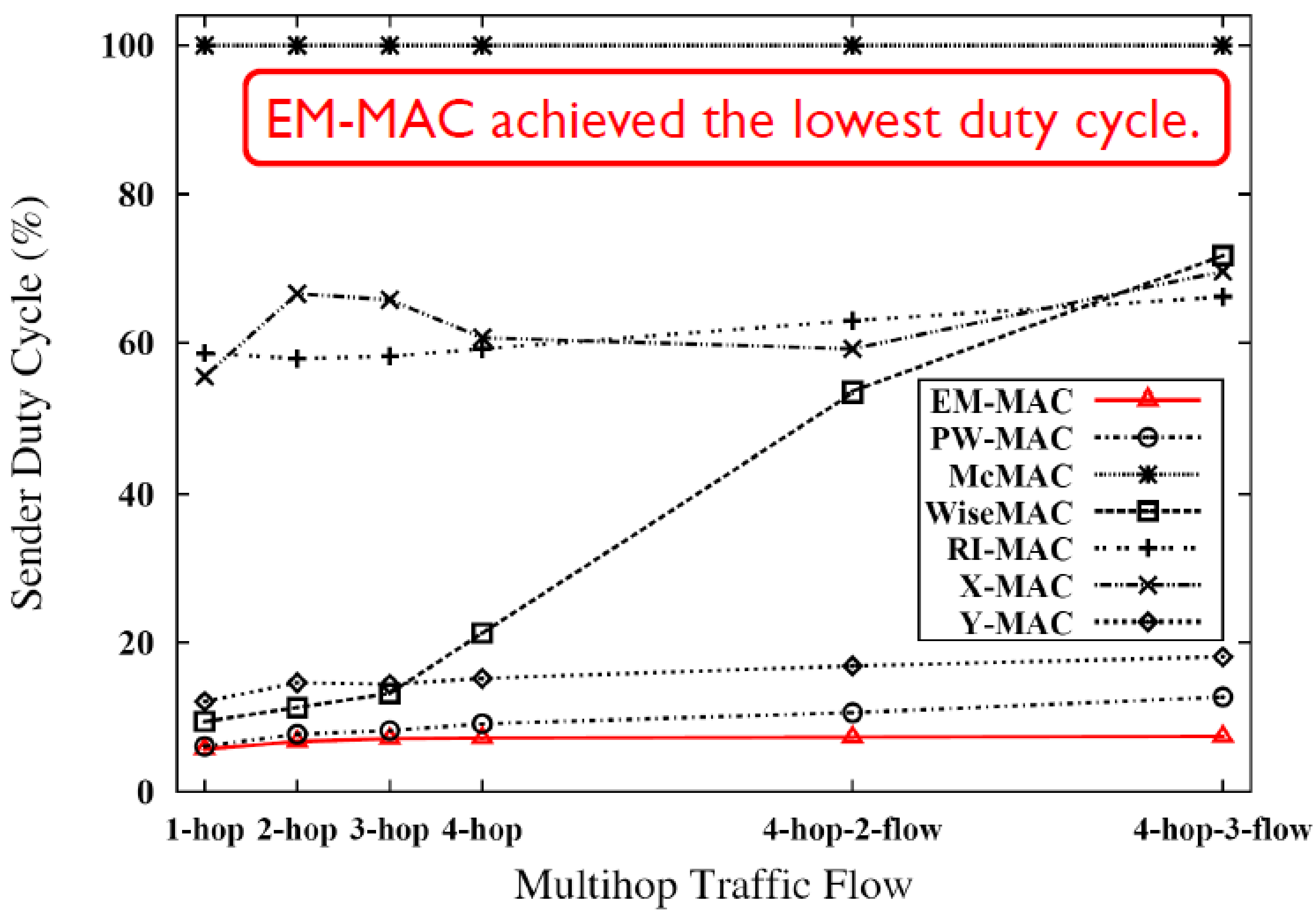
Multihop network performance

Pkt = 28byte
Periodic = 1s
500s x 3times

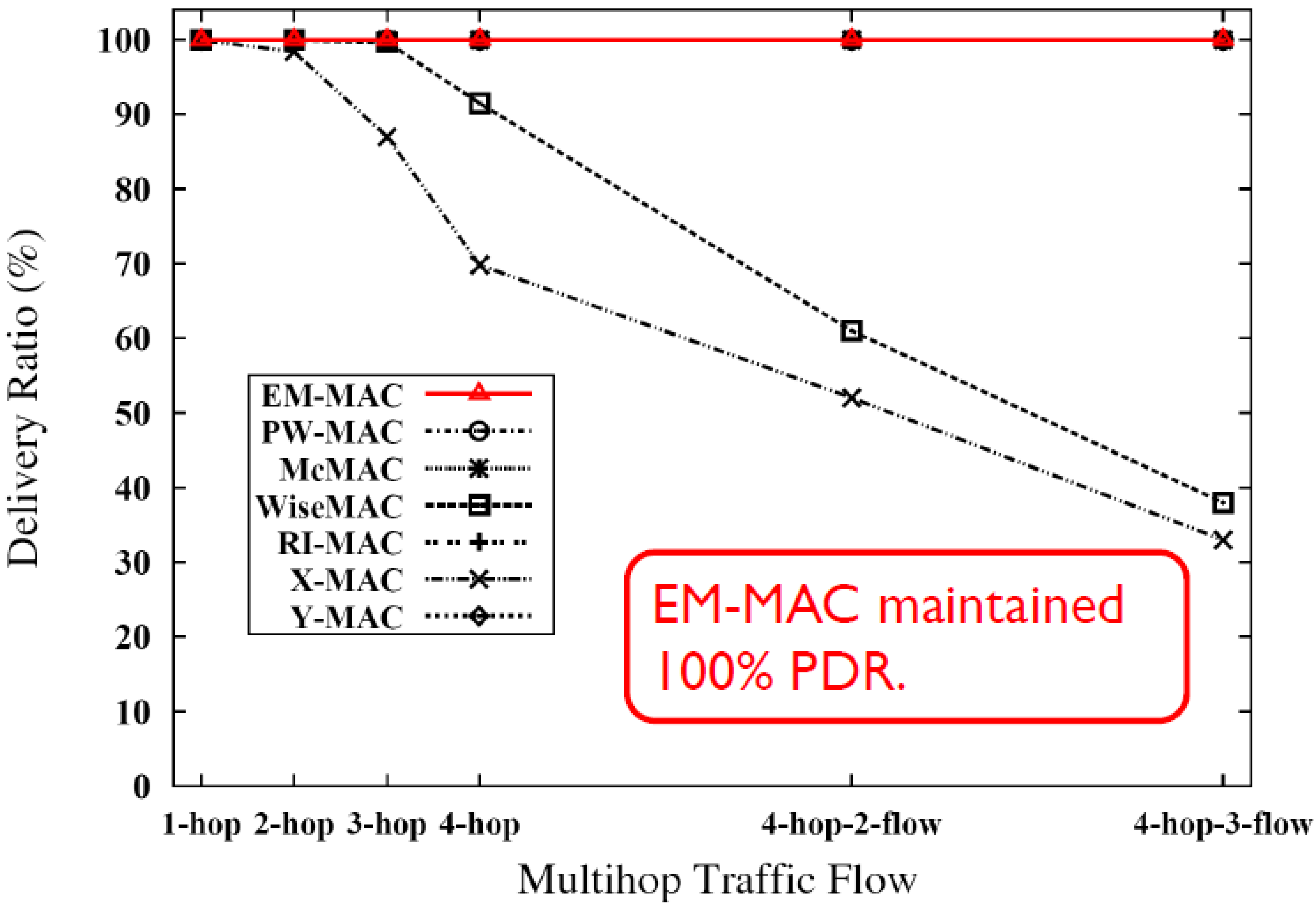


A testbed of **15 MICAz** motes and up to **3 multihop** traffic flows.

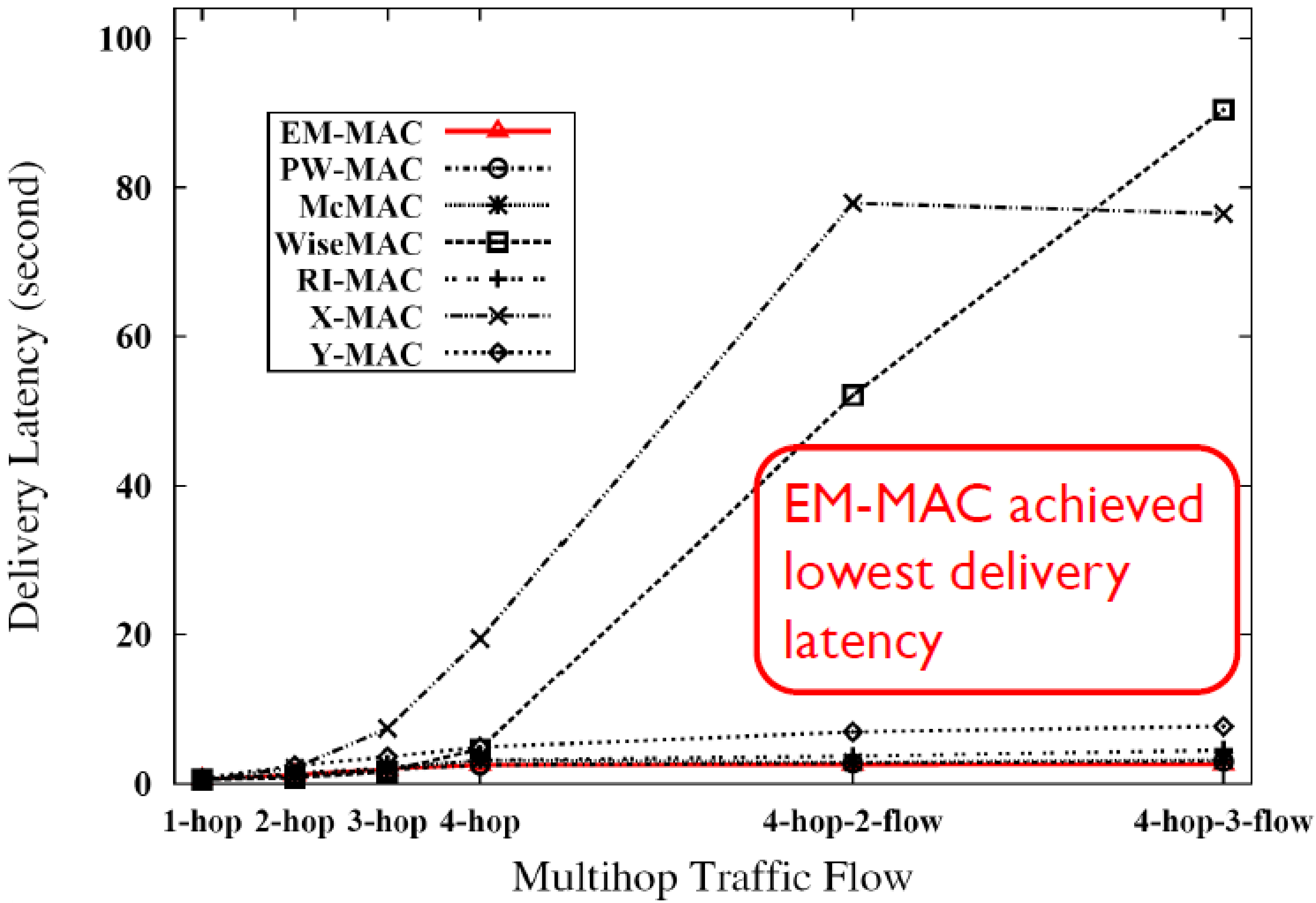
Multihop network performance



Multihop network performance



Multihop network performance



Conclusions

- A dynamic multi-channel and energy efficient MAC protocol for wireless sensor network called the **EM-MAC** is successfully developed and evaluated.
- EM-MAC achieved the **lowest duty cycle** and **smallest packet delivery latency**, while maintaining **100% delivery ratios** compared to other representative energy efficient MAC protocol.


Q&A