The impact of wakeup schedule distribution in asynchronous power save protocols on the performance of multihop wireless networks

Laura Marie Feeney[1,2] Christian Rohner [2] Bengt Ahlgren[1]

[1]Swedish Institute of Computer Science

[2]Uppsala University

IEEE WCNC 2007, Hong Kong

Overview

power save protocols allow nodes to save energy by sleeping

wakeup schedules create spatial/temporal pattern of link availability

hypothesize that some *wakeup patterns* are "friendlier" than others

observe statistical variation in network capacity over a large number of wakeup patterns

result:

- majority of wakeup patterns exhibit similar capacity,
- but extremes are significant ($\pm$ 25% from median)

contribution:

- demonstrate potential benefit of adapting wakeup schedules to improve network performance

Background

multi-hop wireless networks, any-to-any communication

- decentralized, asynchronous, scalable

MAC protocol

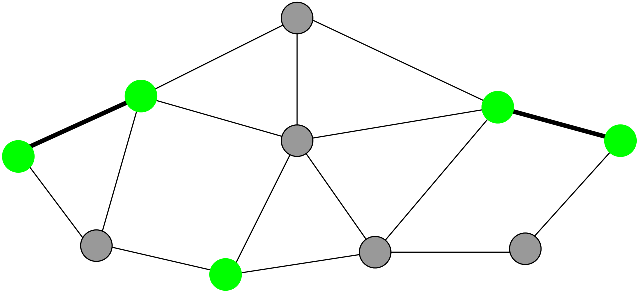
- limited communcation capacity due to multi-hop interference
- CSMA/CA: simple, fully distributed, asynchronous... but inefficient

power save protocol

- nodes must sleep, due to limited battery capacity
- asynchronous network → uncoordinated wakeup schedules
- common solution: independent, periodic wakeup schedules, with deterministic rendezvous mechanism
- Examples: majority schedule (Feeney), quorum schedule (Jiang), block coding (Zheng), A/B schedule (Hurni)

Wakeup schedule

nodes independently follow well-known wakeup schedule



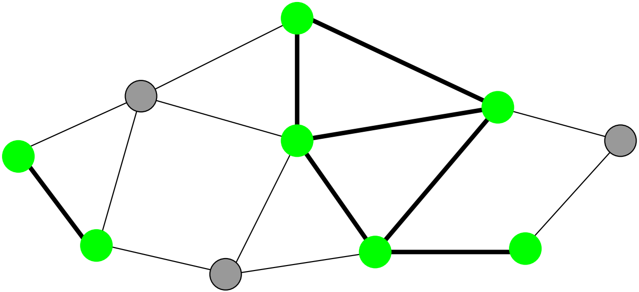
schedule defined to allow nodes to discover and rendezvous with neighbor, despite uncoordinated wakeup schedule

link is available only when both endpoints are awake!

- spatial/temporal pattern of link availablilty

Wakeup schedule

nodes independently follow well-known wakeup schedule



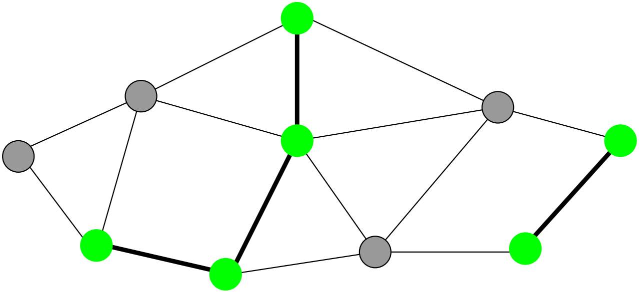
schedule defined to allow nodes to discover and rendezvous with neighbor, despite uncoordinated wakeup schedule

link is available only when both endpoints are awake!

- spatial/temporal pattern of link availablilty

Wakeup schedule

nodes independently follow well-known wakeup schedule



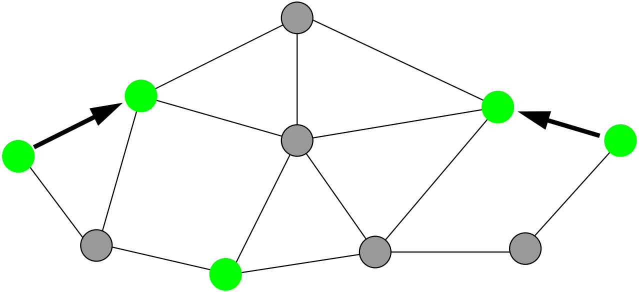
schedule defined to allow nodes to discover and rendezvous with neighbor, despite uncoordinated wakeup schedule

link is available only when both endpoints are awake!

- spatial/temporal pattern of link availablilty

Hypothesis

some wakeup patterns "friendlier" than others

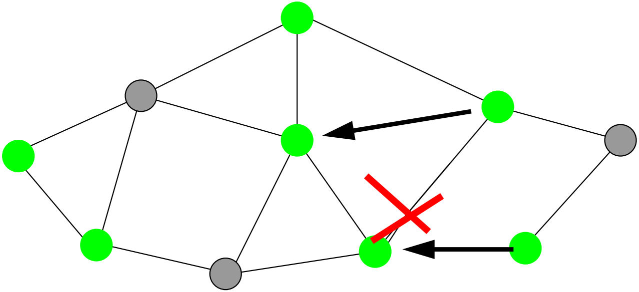


with these nodes simultaneously awake:

- concurrent, non-interfering transmissions (good)

Hypothesis

some wakeup patterns "friendlier" than others

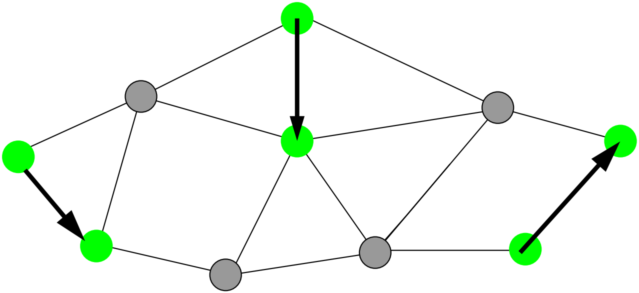


with these nodes simultaneously awake:

- contending transmissions (bad)
  - requires backoff, may result in collisions
  - awake time not useful – wastes battery power

Hypothesis

some wakeup patterns "friendlier" than others



- ideal wakeup pattern separates interfering transmissions
- makes both MAC and power save protocols more efficient
  - depends on traffic pattern
  - practically and computationally (NP-hard) difficult

Problem statement

trivial networks clearly have good and bad wakeup patterns,

but real networks are more complex...

- many competing flows, complex interferences
- are there really wakeup patterns that provide some overall advantage?

experiment: How does the wakeup pattern affect network capacity?

real question: Is it potentially interesting to try to coordinate CSMA/CA media access control and power saving?

Experiment

don't (yet) know *how* to create good patterns

observe statistical variation in performance

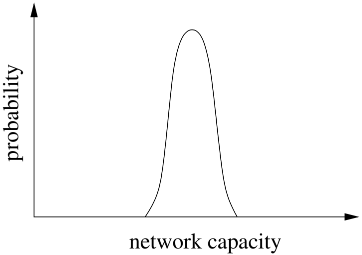
- fix topology and offered load
- randomly generate a large number of wakeup patterns
- measure CBR flow capacity (number of admissible CBR flows)

measurements define some probability distribution

- interested in the shape of this distribution, not absolute values

Distribution

performance measurements define some probability distribution

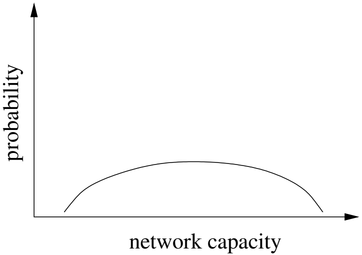


a narrow distribution implies that wakeup pattern has little overall impact

interested in the shape of this distribution, not absolute values

Distribution

performance measurements define some probability distribution



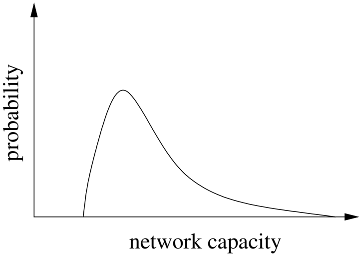
a flat distribution implies high variability

perhaps randomized strategies can be used to improve performance

interested in the shape of this distribution, not absolute values

Distribution

performance measurements define some probability distribution



an asymmetric distribution

interested in the shape of this distribution, not absolute values

Simulation

goal is rapid exploration of the performance space

- statistically many wakeup patterns for each of many topologies
- computationally efficient (some compromises)

use majority power save (55% duty cycle)

- overlap between neighbors guaranteed
- simple, not too sensitive (?)

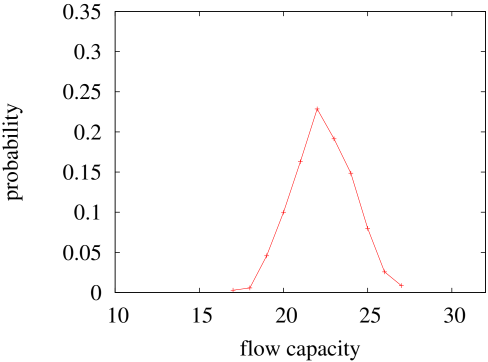
performance metric is number of admissible CBR flows

- fix topology, routing, and offered load
- determine number of admissible flows in offered load

details in paper

Matlab implementation (code available)

Results

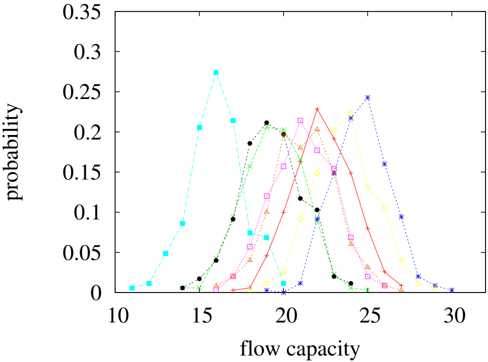


most wakeup patterns support 21-23 flows, but there a few that support 27 flows

1 topology (large rectangle, 100 nodes)

measure number of admissible CBR flows for each of 350 randomly generated wakeup schedules

Results



each topology has a different natural capacity, but similar shape

8 topologies (large rectangle, 100 nodes)

measure number of admissible CBR flows for each of 350 randomly generated wakeup schedules

Results

consistent across range of topologies and node densities (800 scenarios)

- inner quartiles (50% of observations)
  - $\pm 5\%$, relative to median
  - stddev 2% (variation between topologies)
  - corresponds to ≈ 2 flows
- extremes (highest and lowest capacity)
  - $\pm 25\%$, relative to median
  - stddev 5% (variation between topologies)

variation does not depend on offered load (i.e. preferentially admitting short hop-count flows)

- no strong correlation between number and hop-count of admitted flows
- number of total transmissions shows a similar variation

Conclusion

wakeup schedules create spatial/temporal pattern of link availability

investigate the impact of these patterns on network capacity

show that:

- majority of wakeup patterns exhibit similar capacity
- best wakeup patterns provide significantly higher capacity

demonstrate the potential benefit of coordinating wakeup schedules and media access control

- not easy...good wakeup patterns are rare

Thank you!