On-demand Power Management for Ad Hoc Networks

From INFOCOM 2003
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Outline

- Introduction
- Design Space
- On-demand Power Management
- Implementation Based on IEEE 802.11 MAC
- Performance Evaluation
- Conclusion and Future Work

Introduction

- Ad hoc networks
  - Infrastructureless
  - Hard to replace or replenish power
- Ad hoc networks are power constrained
  - Mobile communication devices
    - Battery powered
    - High idle energy consumption
- How to reduce idle energy consumption?
  - Power Management

Introduction

- The node have to monitor the channel and consume power even through the packets are not directed to them , a large amount of energy is consumed unnecessarily
- Lucent IEEE 802.11 WaveLan pc card characteristics (2Mbps)

Modes	Energy Consumption
Sleep Mode	14 mA
Idle Mode	178 mA
Receive Mode	204 mA
Transmit Mode	280 mA

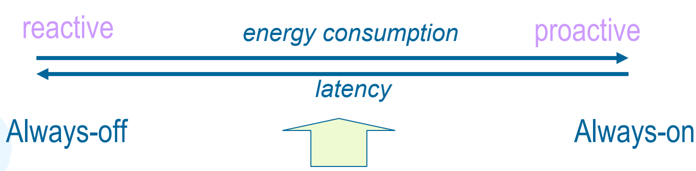
On-demand

- Limited network bandwidth
- Limited storage
- Limited power

- On-demand routing protocols
  - Route discovery in presence of communication
- On-demand power management
  - Use energy in presence of (pending) communication

- Trade-offs
  - Latency to initiate communication
  - Energy consumption

Design Space



- Proactive: always "anticipating" communication
  - No power management
  - PAMAS
  - GAF, Span
- Reactive: relying on posterior information
  - IEEE 802.11 PSM
- On-demand power management: explore the territory in-between

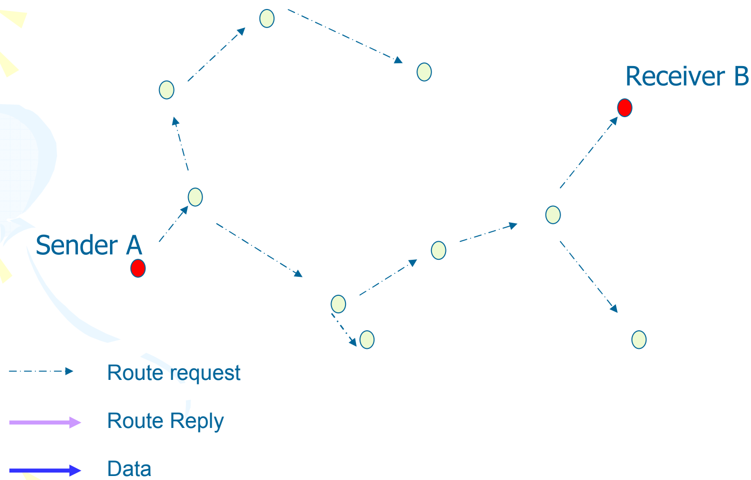
On-demand Power Management

- Design goal
  - Energy-conservation
  - Performance: low loss rate and low latency
- Where to get the “hints” about (pending) communication?
  - Message level: short-term temporal correlation between packet arrivals
  - Network level: routing/control messages give hints for the path of future communication
  - Application level: sender has more knowledge of the traffic pattern

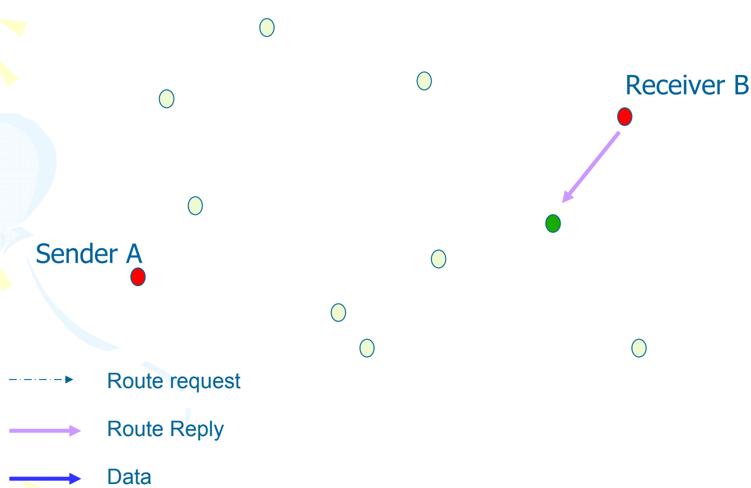
Key Components

- Soft state *keepalive* timer for power management
  - Established/refreshed by communication events
- Packet transmission rule
- Discovering neighbor’s state
  - How to decide if a neighbor is awake
  - How to distinguish if a neighbor moved away or in low-power state

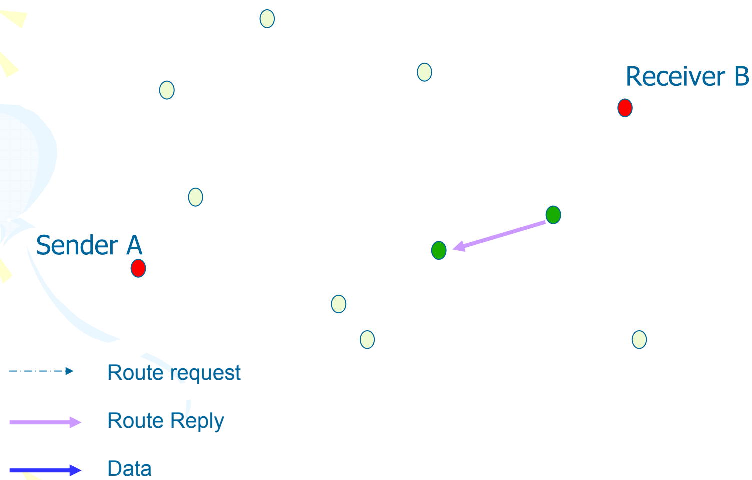
On-demand Power Management



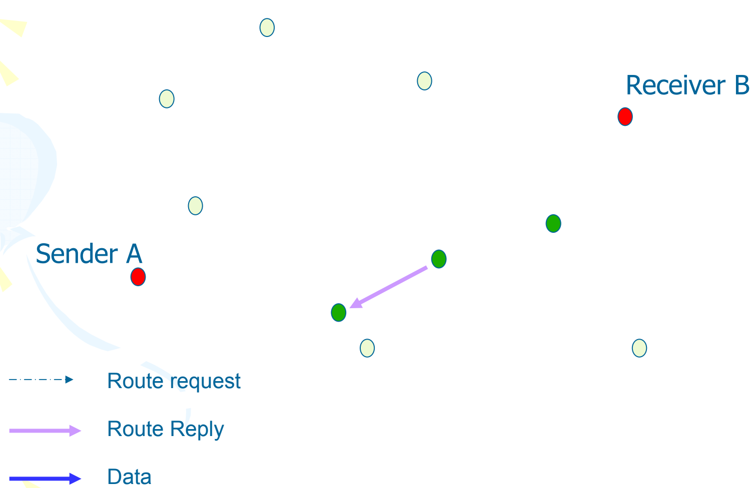
On-demand Power Management



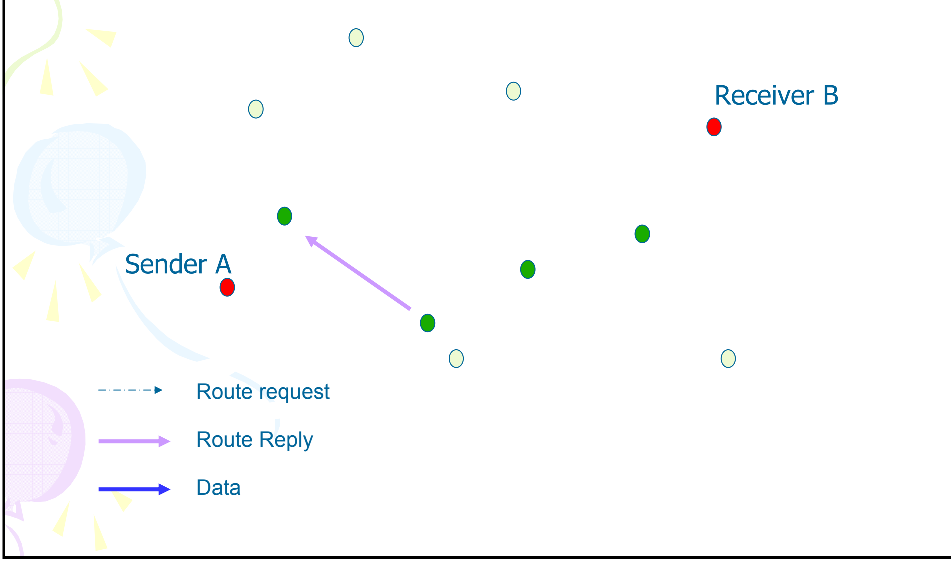
On-demand Power Management



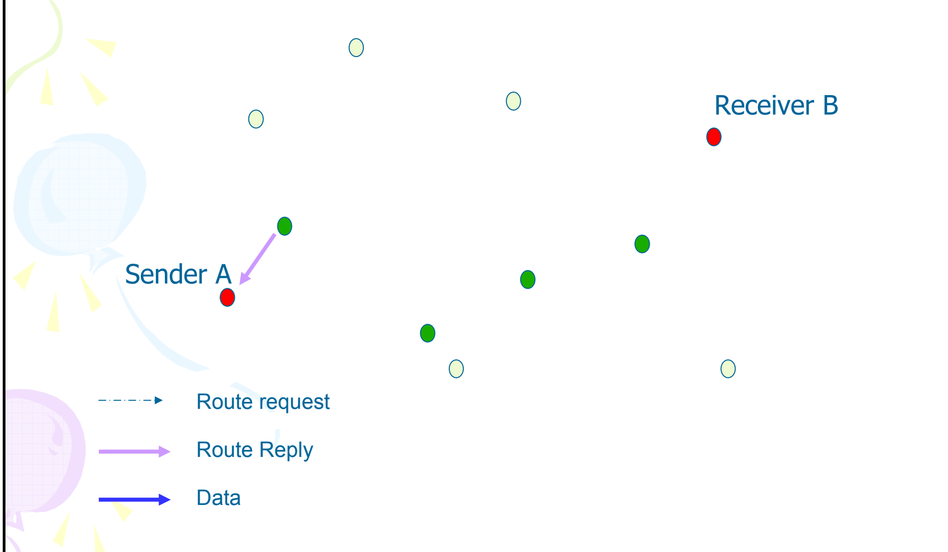
On-demand Power Management



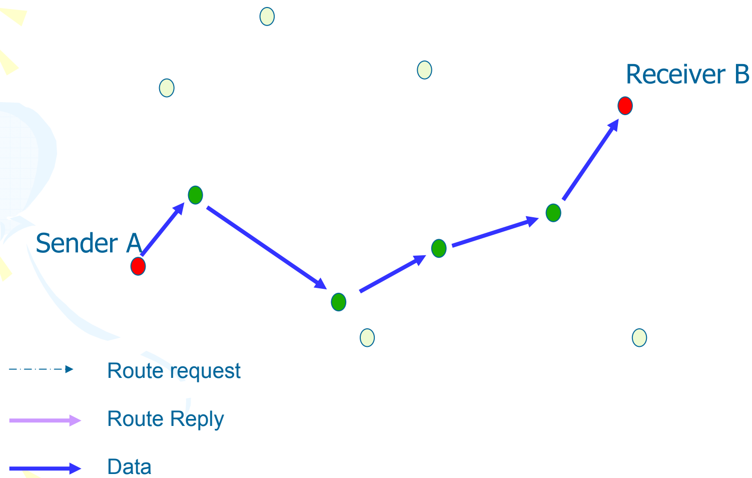
On-demand Power Management



On-demand Power Management



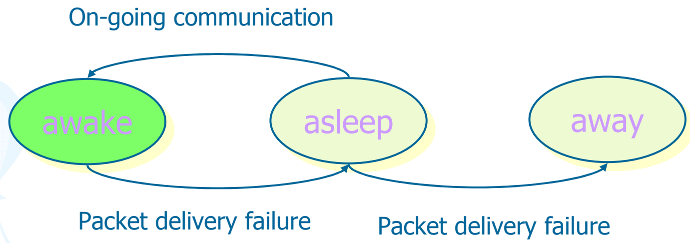
On-demand Power Management



Packet Transmission Rule

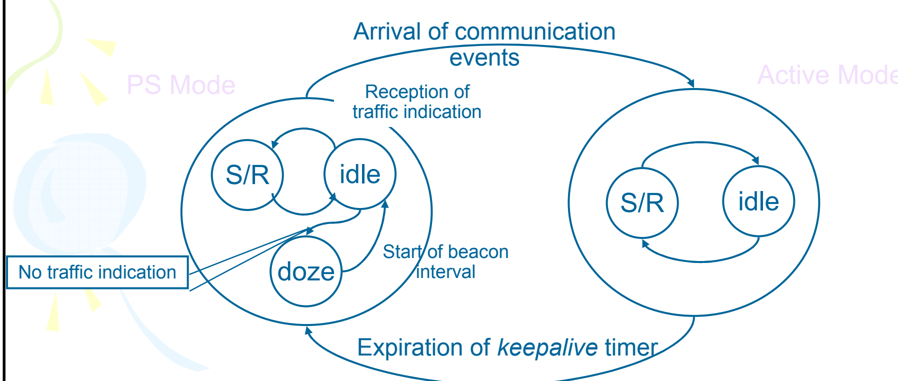
- To an active neighbor
  - direct transmission
- To a sleeping neighbor
  - Buffer the packets first
  - Wakeup the receiver
  - Transmit the packets

Inferring Neighbor's State



- Two-stage transition
  - However, may incur longer delay to detect link failure

Implementation Based on IEEE 802.11 MAC



- A sender always switches to active mode for high-layer packets

Evaluation

- Performance metrics
  - Packet delivery ratio
  - End-to-end delay
  - Energy throughput (bit/J) $= \frac{\text{total bit transmitted (application)}}{\text{total energy consumed}}$
- Scenario
  - Long-lived/on-off traffic
  - With/without mobility

Parameter Setting

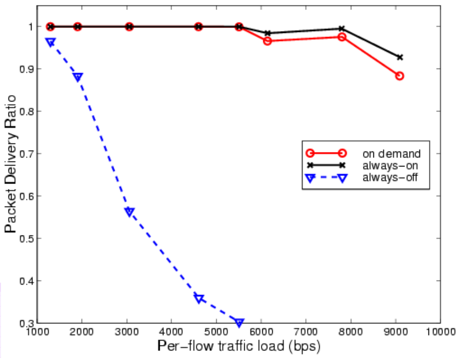
- NS2 simulator energy model (from experimental data of WaveLan card)

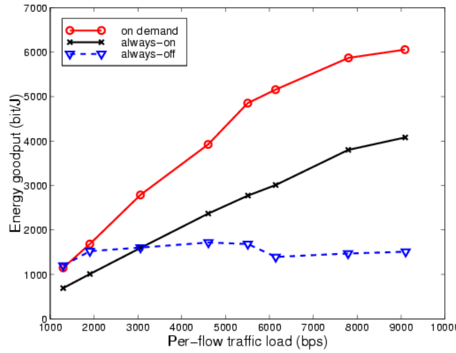
Tx	Rx	Idle	Sleep
1400mW	1000mW	830mW	130mW

- 802.11 MAC: beacon = 0.4s, ATIM = 0.02s,
- On-demand: data keep-alive = 2s, route reply keep-alive = 5s
  - On the order of seconds
  - Not very sensitive to the exact timer value

Static Network with Long-lived CBR Flows

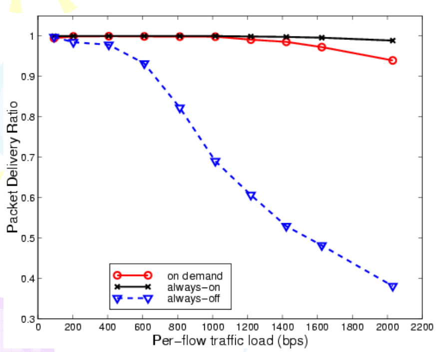
- 1500x300 2-D plane, 50 nodes, 10 long-lived CBR connections

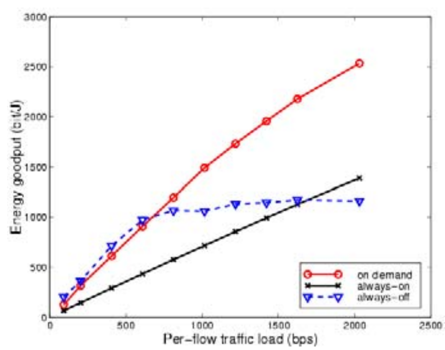




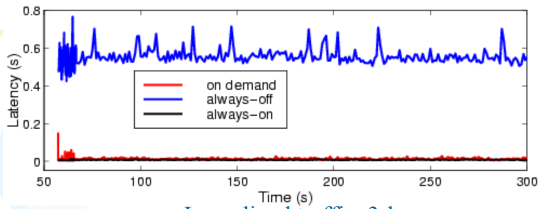
On-off Traffic

1500x300 2-D plane, 50 nodes, 30 on-off connections

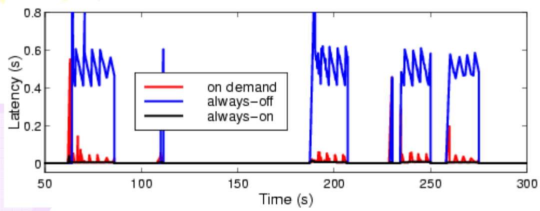




End-to-end Latency



Long-lived traffic, 3-hop



On-off traffic, 3-hop

- Longer initial setup latency
- Small end-to-end latency once the communication path is setup

Conclusion and Future Work

- Contributions
  – Proposed an on-demand power management framework
  – Maintaining a good balance between energy conservation and communication efficiency
- Future work
  – Quantifying the energy-performance tradeoff
    - Fixed keepalive timer ⇒ energy waste at low traffic load
  – Better handling of mobility