CS 525M – Mobile and Ubiquitous Computing Seminar

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A Survey of Energy Efficient Network Protocols for Wireless Networks

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Contents

Introduction

- Wireless devices maximize utility when they can be used “Anytime, Anywhere”
- Power constraints limit short continuous operation time of mobile terminals
- Power management
  - Important topic
  - Lots of recent work in the area

Introduction (Cont.)

- Power breakdown of a typical laptop:
  - Microprocessor
  - LCD (Liquid Crystal Display)
  - Hard disk
  - System Memory
  - Keyboard/mouse
  - CDROM Drive
  - Floppy drive
  - I/O subsystem
  - Wireless Interface card
- Viewed as a hardware problem

Introduction (Concl.)

- Power savings from low-power strategies in network protocols
- Energy incorporation at all layers of protocol stack for wireless networks

Background

- Wireless network architectures
  - Infrastructure: wired backbone, base station
  - Ad hoc: mobiles cooperate to maintain a network
- Protocol Layers
  - OSI model: Physical, Data link, Network, Transport, OS/Middleware, Application

Background (Concl.)

- Physical layer:
  - Increase in battery capacity
    - Extremely limited
    - Not experienced significant growth in the last 30 years
  - Decrease in wireless terminal energy usage
    - Variable clock speed
    - Flash memory
    - Disk spindown

Power Consumption Sources and Conservation Mechanisms

- Sources of Power consumption
  - Communication related
    - Usage at transceiver, destination, intermediate nodes
    - Typically transmit, receive, standby modes
    - Transmit consumes most power
    - Switching from receive to transmit and vice versa
  - Computation related
    - Protocol processing aspects
    - CPU, main memory, and disk
  - Data compression reduces packet length
    - Reduces communication power usage
    - Increases computation power usage
  - Maintain a balance between two power costs

Power Consumption Sources and Conservation Mechanisms (Cont.)

General conservation guidelines and mechanisms

- Retransmissions cost unnecessary power consumption and possible unbounded delays
  - Can’t be avoided due to high error rates
- Collisions avoided at MAC layer
  - Cause retransmissions
  - Can’t be avoided, because of user mobility and constantly varying set of mobiles in a cell
  - Small packet size for registration and bandwidth request

Power Consumption Sources and Conservation Mechanisms (Concl.)

- General conservation guidelines and mechanisms
  - In typical broadcast environments, receiver on at all times
    - Forwards packets destined for the mobile
    - Could use broadcast schedule
    - Could turn off transceiver when not used for period of time
  - Significant time and power switching between transmit and receive modes
    - Contiguous slots for transmission or reception
  - Request multiple transmission slots with a single request
  - Scheduling should be done by base station
    - Consider battery left
  - Error control schemes should balance:
    - ARQ (automatic repeat request) – retransmissions
    - FEC (forward error correction) – longer packets
  - Routing
    - Equal battery power depleting routing protocols
    - Avoid routing through nodes with low battery
    - Periodic updates of routing can be reduced

MAC Sublayer

- IEEE 802.11 standard
  - To conserve power mobile switches to sleep mode and informs base station
    - Base station buffers packets
    - Base station periodically sends beacon
    - Mobile wakes up and listens for beacon, responds and receive buffer packets
    - Might cause Quality of service (QoS) issues
  - Experimental measurements show broadcast vs. point-to-point
    - Fixed cost per packet - Broadcast better (less overhead)
    - Incremental cost per packet size is the same

MAC Sublayer (Cont.)

- EC-MAC protocol
  - Infrastructure protocol based on reservation and scheduling
  - Frame Synchronization Message (FSM) beginning of each frame
    - Synchronization information
    - Uplink transmission order
  - EC-MAC – scheduler
    - voids collision, hence avoids retransmission
    - Optimizes mobile receives and transmits contiguously
    - Receivers don’t need to monitor lines
    - Contiguous slot allocation to reduce transceiver turn around

MAC Sublayer (Concl.)

- PAMAS protocol
  - Mobiles not able to send and receive turn off wireless interface
    - Turns off when:
      - Has no packets to transmit and a neighbor begins transmitting packets not destined for it
      - Has a packet, but a neighbor pair is communicating

LLC sublayer

- Adaptive error control with ARQ
  - New design metric ratio between energy efficiency and data delivered
    1. Avoid persistence in retransmitting
    2. Trade off number of retransmission attempts for probability of successful transmission.
    3. Inhibit transmission when channel conditions are poor.
  - Enters probing mode when error is detected
  - Under slow fading channel conditions ARQ probing is superior to ARQ
  - Energy efficiency may be maximized by decreasing transmission attempts and/or transmission power

LLC sublayer (Cont.)

- Adaptive error control with ARQ/FEC combination
  - Error control scheme changes dynamically
    - Based on service quality parameters
      - Such as packet size and Quality of server requirements
    - May need to change over time

LLC sublayer (Concl.)

- Adaptive power control and coding scheme
  - Each Transmitter operates at a power code pair
    - Power level lies between a specified minimum and maximum
    - Error code is chosen from a finite set
  - Timeframe - time between each iteration
  - After each timeframe evaluate word error rate.
    - If acceptable, continue with current power code pair
    - If not, recalculate power code pair

Network sublayer

- Considering ad hoc networks
- Routing packets and congestion control
- Typical routing algorithms in ad hoc networks
  - Use frequent topology updates resulting
    - improved routing
    - consumes bandwidth
  - Use infrequent topology updates resulting
    - decreased update messages
    - inefficient routing, occasional missed packets

Network sublayer (Cont.)

- Unicast traffic
  - Traffic which packets are destined for a single receiver
  - Metrics to study performance of power-aware routing protocols
    - Energy consumed per packet
    - Time to network partition
    - Variance to power levels across mobiles
    - Cost per packet
    - Maximum mobile cost
  - Minimize all but Time to network partition

Network sublayer (Concl.)

- Broadcast traffic
  - Packets are meant for all mobiles in the systems
  - Learn network topology in wireless
  - Broadcast tree approach
    - Priority for routing packets:
    - Lower cost per outgoing degree
  - Algorithm for finding tradeoff between greater hops reached and transmission power

Transport sublayer

- Reliable end to end data delivery service (TCP)
- TCP degrades on wireless
- Three groups of schemes
  - Split connection
    - Hides wireless network from wired
  - Link layer protocols
    - Hides link layer loss by forward error correction and local retransmission
  - End-to-end protocols
    - Modified TCP more sensitive to wireless environment

Transport sublayer (Concl.)

- Energy consumption analysis of TCP
  - Energy consumption measured by successful transmissions per energy unit
  - Error control mechanism is the key to balancing energy and throughput
  - TCP-Probing
    - data transmission is suspended and a probe cycle started, when data is delayed or lost
    - Probe segments are just headers
    - TCP monitors network through probe-cycles
    - When two consecutive roundtrips, invoke regular congestion control

OS/Middleware

- CPU operated at lower speeds by scaling down supply voltage
- Predictive shutdown in times of inactivity
- Power aware scheduling techniques

OS/Middleware

- **Application Layers**
  - Load partitioning
    - Mobile host play role of intelligent terminal
  - Proxies
    - Detect change in bandwidth and battery power, adjust transmissions
  - Databases
    - Embedded indexing
  - Video processing
    - Reducing the number of bits in the compressed video stream generated by the video encoder
    - Discarding packets by WNIC card

Summary

- Wireless services continue to add more capabilities
- Low power design is an important research topic
- Power conservation is typically physical
- Power conservation within the wireless protocol stack is crucial for wireless services expansion’s viability

Questions?