Energy Efficient Wireless Networks

CS 260

Fall 2003
General Information

• Who am I? – Dr. Srikanth Krishnamurthy
• Where can I be found? – Surge 334
• When can I be found? – Office hrs: W 10-11 A.M. – or by e-mail appointment.
• My E-Mail: krish@cs.ucr.edu
• My Web Page: http://www.cs.ucr.edu/~krish
What can I expect in this seminar?

Good Question !!!

It depends on you – it is your course.

I can tell you what I would like to expect 😊

• Energy
• Enthusiasm
• Discussion
• Evolution
Pre-Requisites

• Preferred: Either should have taken CS 204 or should be concurrently enrolled in CS 204 – Advanced Computer Networks.

• Probably Sufficient: CS 164 – Undergraduate Computer Networks or equivalent.

• Some knowledge of wireless networks – if you don’t know ask – either I will tell you or refer you to literature.

• High energy, passion to do wireless research.
Evaluation -- I

• Of course a course term project.
• Need new ideas, analysis of prior work or comparison of schemes.
• Simulations are ideal – ns 2.0, glomosim.
• You should target publishing a paper.
• My recommendation is to have groups of two.
• The project report be worth 65% of your grade.
Evaluation II

- What about the other 35%?
- Need to tell you how the seminar will be spread out.
  - Stage I – About 3 classes – I will talk.
  - Stage II – About 12 classes – I will talk for half the class and you will talk for half the class.
  - Stage III – The last 6 classes or so – you will talk and I will listen.
Stage I

- I will cover a few papers and topics on energy efficiency in Wireless Networks.
- Probably two papers per class – ambitious.
- You can ask questions at any time – also look at my presentations to prepare for your own.
Stage II

- I will cover more papers - hopefully will give you a list soon.
- Each class, one of you will present a paper of his choice on energy efficient networks - lots of choices - choose from the papers I have not covered.
- Send me an e-mail a week in advance as to which paper you will talk about.
- My talk ~ 30 minutes, Your talk ~ 30 minutes.
- Discussion ~ 20 minutes.
• So the 35 % is split into:
  • 20 % for your paper presentations.
  • 15 % for your participation in discussions.
  • Note: Attendance is not the only thing – we need participation – Ideas need to be generated, the papers strengths and weaknesses need to be discussed.
Paper Presentations

- For the paper presentations - keep to 30 minutes - strict time limit.
- You would need to restrict yourselves to about 20 slides.
- You need to say:
  - What is the main point of the paper?
  - What do they try to do? How do they do it?
  - Do they succeed? If yes, why? If not why?
  - What did they leave out?
  - Is there room for improvements, alternatives?
• I will provide a list of the order of presentations.
• Random to the extent possible - Some people who have been in the system for a while may be asked to present first.
• Questions ?
Stage III

- Last three weeks or so.
- Each person gives a half hour presentation on the things done for the project.
- To refresh - the project has to have something new and has to be “properly” motivated.
- Nitty gritty details can be covered here.
- Hopefully the first set of presentations and papers will give you ideas on what to do.
Reports and When to do What?

- Start thinking about the project from Day 1.
- Read some survey, or general papers and try to formulate ideas.
- My initial talks will also cover such papers and point out problems when possible.
- You would need to write a two page (12 pt font) proposal. Send this to me by the end of October - October 30th Thursday is the Strict Deadline.
- Finally, you would submit a paper (two column like in conference proceedings) not to exceed 10 pages on the last day of class.
Any other questions?
Clarifications?
Why is Energy Important?

- Mobile Devices run on Batteries
- Limited Energy
- Some wireless networks - you can recharge, power outlets are available etc.
- For some other deployments - energy efficiency is vital.
  - Ad hoc network deployments in scenarios such as military, disaster relief.
  - Sensor Networks.
- In any case, extending battery life is good.
How can we save on Energy?

• Types of cost: Communication and Computation.

• Typically computation costs are smaller than communication costs.

• Reduction in costs:
  • Transmission Power Control - reduce transmission power.
  • Reduce Overhead - reduce quantum of transmissions.
  • Sleep when possible - low battery consumption.
  • In-network data processing to reduce quantum of data transmitted - sensor networks.
What I will try to do for the rest of the class & a precursor for next class


& Next Class:


NOTE: Listening to presentation is not enough, please read the papers.
Sensor Networks

- Tiny sensor nodes, typically wireless capable of data sensing, processing and communications.
- Deployment in inaccessible terrains or disaster relief operations.
- Many nodes – very large in number.
- Co-operation among sensors needed.
- Since the deployment is typically in inaccessible terrain – battery life critical for the functioning and longevity of the network.
Information flows from Sensor Network to User

Figure 1. Sensor nodes scattered in a sensor field.

Figure from Reference [1].
Block Representation of a Sensor

Figure 2. The components of a sensor node.

Figure from Reference [1].
• Some sensors may have solar power extraction capabilities.

• Typically, the sensor sub-units need to fit into the size of a matchbox.

• Main task of a sensor node is to detect events, perform quick data processing and then transmit the data - possibly route it to the sink.
Differences between sensor and ad hoc networks.

• Ad hoc networks - infrastructureless wireless networks - dynamically changing topology.
• Sensors are typically much more in number
• More prone to failure - changes in topology due to failures, sensors going to sleep, etc.
• Data transport has a specific pattern.
• Sensors are very limited in terms of power, computational capabilities and memory.
Protocol Stack

- Notice that we have a power management plane - in general there are management planes.
- We need power efficiency at all layers of the protocol stack.

Figure 3. The sensor networks protocol stack.

Figure from Reference [1].
Physical Layer

- Thus far, 915 Mhz ISM band.
- Shorter ranges
  - Higher transmission needed for reaching longer distances – power drops off as $d^n$, where $d$ is the distance at which the signal power is measured.
- Good modulation schemes – we won’t worry about this in this course.
MAC Layer

- Bluetooth
  - Master Slave configuration – probably not suitable for Sensor Networks.
- MANET – Mobile Ad Hoc Networks – typically use 802.11 – not power efficient – requires constant monitoring of the channel.
MAC Layer (continued)

- **CSMA Based** -
  - Contention based random access.
  - There have been schemes that try to take into account correlated data traffic transfers.
  - In one of the papers, there is an attempt to take into account the rates of “local” originating traffic at a sensor and the route-thru traffic to ensure MAC fairness.
  - Important to manage the listening mechanism and back-off times.
Self-Organizing Medium Access Control (SMACS)

- By Dr. Greg Pottie’s group at UCLA (refer [1]).
- SMACS provides network startup and link-organization.
- Frequency hopping allowed – sensors discover their neighbors and establish transmission/reception schedules.
- Each link consists of a pair of time-slots that operate on fixed frequencies.
- Random wake up schedule during connection phase and nodes sleep during idle time slots.
- No need for network wide synchronization.
The Eavesdrop and Register (EAR) protocol

- Mobile nodes take responsibility for registering static nodes.
- Each static node is affiliated with a mobile node and sensed data is ultimately relayed to the mobile node.
- Possibility of fragmented subnets.

→ SMACS and EAR are possible papers that may be taken up for longer presentations.
→ We will see some MAC protocols later.
Routing -- I

• Various metrics possible
  • Total power available (PA) along a path.
  • Minimum Energy Route
  • Maximum (minimum PA) on a path.
Routing -- II

- $\alpha_i$ is the cost of link $i$.
- $PA \rightarrow$ total available power at the particular node.
- Node T is the source (a single sensor).
- Data is to be sent to sink.

Figure from Reference [1].
In-Network Data Aggregation

- Data aggregation useful when it does not hinder collaborative effort of sensor nodes.
- Attributes specify the kind of data being sensed - whether aggregation is possible etc.
- Combining data from a plurality of sensor nodes into a set of meaningful information.
- Also referred to as Data Fusion.
- E.g. If three sensors in a particular area report a temperature > 70 degrees, then a single report saying so will suffice.
A Reverse Multicast Tree

B fuses data from C and D

C performs data fusion - the data received from nodes E and F is fused.
Interests and Attributes

• How do the sensors know when to send data?
• Attribute based
  • One possibility is that the sink may broadcast the interest.
  • Sensors may broadcast an advertisement for the available data.
  • Typically application dependent.
Flooding and Broadcasting

- Of interest not only in sensor nets but also ad hoc nets.
- In flooding each node repeats the broadcast from the source - expensive.
- Duplications, overlap $\rightarrow$ wasteful.
- Gossiping - node does not broadcast but picks a randomly selected neighbor to send the packet - this neighbor does the same thing and so on.
- Delays, and could lead to wastage as well.
- Intelligent power efficient broadcast needed.
Clustering and LEACH

• Clustering helps in organized access etc. – reduction in wasteful collisions.

• Low-Energy Adaptive Clustering Hierarchy (LEACH) is a clustering based protocol that helps reduce energy dissipation.

• At set up, each node computes a random number and decides whether to become a clusterhead.

• This random number takes into account whether the node was a clusterhead in the recent past.
LEACH

• Once the clusterheads are selected they announce their presence.

• Nodes join clusterheads.

• Clusterheads assign time on which sensors can send data - TDMA based approach.

• This is steady phase.

• Network remains in steady phase for a while and then reverts to set up phase - new clusterheads are selected.
Directed Diffusion

- By Intanogwiwat et al (Dr. Estrin’s group UCLA).
- Sink sends out an interest or task description.
- Attribute value pairs describe a task.
- Each sensor node stores interest-entry in cache.
- Interest Entry contains a time-stamp and several gradient fields – back towards the sink.
- As the interest is propagated the gradients from each source to the sink are set up.
- When there is data for the interest, source sends data along the interest’s gradient path.
Pictorial Example of Directed Diffusion

Figure from Reference [1].
Transport Layer

- TCP and UDP are not appropriate – not geared towards sensor networks.
- There needs to be an attribute based transport layer.
- Reliability or the “credibility” of an event as opposed to the reliability of an individual byte of importance.
- OPEN AREA of Research.
- There is a paper by Aykildiz et al in MOBIHOC 2003 – ETSI – we will look at this later.
Other topics

- Effects of density – how can we exploit?
- When do we turn sensor nodes on and off?
- Time Synchronization – needed for arbitration of access – else collisions can waste channel capacity and energy.
- Moving sensors – how do we move?
- Sink trajectory control
- Internetworking sink nodes
- Anycasting to any of the sink nodes.
Important Resources

- ACM MOBICOM
- ACM MOBIHOC
- IEEE INFOCOM
- Workshop on Sensors and Applications (WSNA)
- Journals.
- The survey paper has a set of websites that you may want to visit.