CSC7290: Advanced Computer Networking

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Objectives of the course

- **Ultimate goal:**
  - You become an expert in network and system design and analysis, which are fundamental tools in scientific and technological innovations

- Humble course objectives:
  - To help students understand the foundational principles and techniques of network design and analysis
  - To help students appreciate why networks have been designed as they are today
  - To build up students' capability in enhancing the state of the art in computer networking

**Suppose we are building the Internet from scratch up:**
How to select among different solutions to a problem (e.g., routing, error control, congestion control)?
Topics to cover

- Prelude
  - How to have a bad career in innovation/research
  - General principles on systems development & research

- Performance evaluation techniques and their applications to computer networks
  - Common mistakes and how to avoid them
  - Selection of techniques and metrics
  - Review of basic probability theory and statistics
  - Experiment design and analysis
  - Simulation
  - Summarizing measured data
  - Comparing systems using sample data
  - Mathematical regression models
Optional topics: if time permits

- Stochastic models of computer networks and their applications
  - Stochastic processes and queuing theory
  - Applications to protocol and system analysis

- Formal models of distributed algorithms and their applications to network protocol analysis
  - Network process: syntax and semantics
  - Models and analysis of network processes: specification and proof techniques
  - Applications to network protocol design and analysis

- Network optimization and control
Two major components of the course

- **Lecture**
  - Focus on basic techniques and tools

- **Project**
  - Applying the basic techniques and tools in real-world applications, especially in *innovative, emerging* networking technologies
    - wireless and sensor networks
    - Vehicular networks
    - disruption tolerant networks
    ...

These techniques apply to fields far beyond computer networking!
Textbooks

Required:


Recommended references:

Logistics

- Class timings
  - MW 3:00pm-4:20pm in *314 State Hall*

- Office hours
  - MW 4:30pm-5:30pm in *454 State Hall*, or by appointment

- Teaching Assistant
  - Mr. Tung Nguyen
    - dx1908@wayne.edu
  - Office hours
    - Tuesdays & Thursdays: 5:00-6:00pm in *312 State Hall*, or by appointment
Logistics (contd.)

- **Prerequisites**
  - Basic knowledge of computer networks, for instance, materials covered in CSC6290 or equivalent
  - Elementary probability theory, statistics, and mathematical logic
  - Or consent of instructor.

- **Course website**
Logistics (contd.)

- Grading
  - Class participation: 10%
  - Randomized quiz: 10%
  - Homework assignments: 45%
  - Project: 35%

- Letter grades will be assigned based on performance *relative* to other students; A tentative grading scale:
  - A: 93-100
  - A-: 90-92
  - B+: 85-89
  - B: 80-84
  - B-: 75-79
  - C+: 70-74
  - C: 65-69
  - C-: 60-64
  - F: 0-60
Randomized quiz

- A quiz question before (almost) every lecture session
- A student is asked to answer the question, and will be graded
- Each student will be asked twice on average in the whole semester; the best of your quiz scores is used for your grade in the “randomize quiz” category
- So, please review the lecture materials after each session!
Project

- Evaluate the performance and/or analyze the properties of selected protocols/systems in the following fields:
  - *Vehicular sensor networks*
    - Intra-vehicle sensing and control
    - Inter-vehicle sensing and control
    - Urban/participatory/opportunistic sensing via vehicles
Project (contd.)

- *Sensor networks* in
  - Healthcare
  - Engineering: structural health monitoring, factory automation & industrial control, etc.
  - Homeland security and military
  - Daily life: urban sensing, security monitoring
  - Scientific study: environmental engineering, social sciences, etc.

- Can focus on issues such as MAC, routing, transport control, data storage and querying, and localization.
- **Wireless mobile networks** in
  - traffic control: real-time road traffic condition detection and control
  - Auto safety: DSRC
  - Homeland security
  - Social networks

- **Heterogeneous networks**
  - integrated wireless networks (sensor networks, WiFi, cellular) and the Internet etc.

- Networking technologies for emerging economies
  - network properties: wireless, mobility, intermittent connectivity ...
  - network services: telemedicine, mobile banking, e-retailing, stored data and voice messaging, remote education, local content and news, security, policing, etc.

- Other topics of your choice (with consent of instructor)
Project (contd.)

Overview of an emerging networking technology ---

**Wireless Sensor Networks**

- Opportunities
- Challenges in network/system design
Retrospect on computing & networking

ENIAC: first computer (1945)

Apple II: first successful PC (1977)

Laptop, PDA ... (1979 -)

First computer network

Internet, wireless ...
What if

Ubiquitous Computing & Networking + Sensing & Control

→ **Ubiquitous, fine-grained** sensing & control
Sensor nodes

- A XSM sensor node (2004)
  - 8MHz CPU, 4KB RAM, 128KB ROM
  - Chipcon CC1000 radio: 19.2 kbps
  - Infrared, acoustic, and magnetic sensors
  - Sounder
    ...

- Many more (2001 - )
Wireless sensor networks: *innovative ways of interacting with the world* ...

**Science:** ecology, seismology, oceanography ...

**Engineering:** industrial automation, precision agriculture, structural monitoring ...

**Daily life:** traffic control, health care, home security, disaster recovery, virtual tour ...
Tiny computers that constantly monitor ecosystems, buildings, and even human bodies could turn science on its head.

— Nature, March 2006

The use of sensornets throughout society could well dwarf previous milestones in information revolution.

— National Research Council report, 2001
Sensor networks of today

Redwood ecophysiology

Wind response of Golden Gate Bridge

Intruder detection, classification, and tracking
ExScal

- Field project to study scalability of middleware and applications in sensornets
- Deployed in an area of \( \sim 1,300 \times 300 \) m
- 2-tier architecture
  - Lower tier: \( \sim 1,000 \) XSM, \( \sim 210 \) MICA2 sensor nodes (TinyOS)
  - Higher tier: \( \sim 210 \) IEEE 802.11b Stargates (Linux)
Other sensornet projects/applications

- Healthcare
- Social networking
- Industrial control
- Precision agriculture
- Homeland security
- Ecosystem conservation
  ...
  ...
Healthcare

Medical implant: artificial retina ...

Assisted living: health monitoring & coordination ...

Health-environment monitoring: air quality, noise, bio & chemical-agent ...
Social dynamics and networking
BikeNet: mobile sensing system for cyclist experience mapping

- Monitor cyclist performance/fitness: speed, distance traveled, calories burned, heart rate, galvanic skin response, etc
- Collect environmental data: pollution, allergen, noise, and terrain condition monitoring/mapping, etc
Vehicular sensor networks
Industrial control: Intel Semiconductor Factory monitoring ...

Preventative equipment maintenance: monitoring vibration signals ...
Precision agriculture: smart vineyard

monitor soil humidity, temperature, chemistry ...
Homeland security: BioWatch ...
The turtle came out of the water to sun itself for only brief periods and went back into the colder water ...
SealNet: use nature to help scientific study

- To measure ocean’s *temperature* and *salinity* levels, as well as the seal’s location and depth.
- Sensing data are collected for every dive; Each time the seals resurfaced to breathe, that data was relayed via satellite to certain data centers in US and France.
- As the seals migrated and foraged for food during their winter journey, they circumnavigated the Antarctic continent and its continental shelf, diving down to 2,000 feet more than 60 times a day.
• New applications (e.g., SensorWeb (MSR), sensor-rich vehicular networks) and startups keep emerging ...

  - A seamless cyber-physical world of intelligent computing and networking agents ...
Are sensornets mature enough to be readily used in practice?

Each large scale project may well take

- 5 professors
- 10 PhDs
- 20 Master and undergraduate students
- A few months/years of hard work
- $$$
- ...

Components of one application do not work for another!
Challenges of sensor network design?!
Challenging aspects of sensor networks

- Dynamic, unreliable, and interference-prone wireless channels
- Reliable messaging

Indoor testbed at OSU; 3 feet node separation
- 300 data points for each distance, with each data point representing the status of 100 broadcast transmissions
Challenging aspects of sensor networks

- Dynamic, unreliable, and interference-prone wireless channels
  - Reliable messaging

- Resource constraints (e.g., bandwidth, energy, memory)
  - Resource-efficient services, sensor network architecture

- 19.2 kbps
- 2 AA batteries
- 4KB RAM
  ...
Challenging aspects of sensor networks

- Dynamic, unreliable, and interference-prone wireless channels
  - Reliable messaging

- Resource constraints (e.g., bandwidth, energy, memory)
  - Resource-efficient services, sensornet architecture

- Application diversity (e.g., traffic patterns, QoS requirements)
  - Application-adaptivity
    - Periodic data collection
    - Can tolerate certain data loss and delay
    - Infrequent aperiodic report of hazards
    - Need reliable and real-time report
Challenging aspects of sensor networks

- Dynamic, unreliable, and interference-prone wireless channels
  - Reliable messaging

- Resource constraints (e.g., bandwidth, energy, memory)
  - Resource-efficient services, sensornet architecture

- Application diversity (e.g., traffic patterns, QoS requirements)
  - Application-adaptivity

- Complex faults and large system scale
  - Dependability despite fault complexity and system scale
    - Node/link failure, state corruption, system signal loss, malfunctioning sensor, etc
    - Increased overall probability of fault occurrence
    - Fault propagation
Challenging aspects of sensor networks

- Dynamic, unreliable, and interference-prone wireless channels
  - Reliable messaging

- Resource constraints (e.g., bandwidth, energy, memory)
  - Resource-efficient services, sensornet architecture

- Application diversity (e.g., traffic patterns, QoS requirements)
  - Application-adaptivity

- Complex faults and large system scale
  - Dependability despite fault complexity and system scale

- Heterogeneity
  - Architecture and service provisioning in integrated systems
Challenging aspects of sensor networks

- Dynamic and potentially unreliable wireless channels
  - Reliable messaging
- Resource constraints (e.g., bandwidth, energy, memory)
  - Resource-efficient services
- Application diversity (e.g., traffic patterns, QoS requirements)
  - Application-adaptivity
- Complex faults and large scale
  - Dependability irrespective of scale
- Growing heterogeneity
  - Architecture and service provisioning in integrated systems
Project (contd.)

- Rules
  - Students are allowed to form groups in doing projects, but the number of students per group should be no more than 3
  - First choose one of the above technical fields and focus on a specific problem (e.g., routing) in your selected field
  - Evaluate and analyze different solutions to your chosen problem
  - Report your findings in a *scientific* manner

- Deliverables
  - In-class presentation
  - Written project report (in the form of a technical paper)
Project (contd.): related resources

- TinyOS
  - TinyOS Community Forum, [http://www.tinyos.net/](http://www.tinyos.net/)
  - TinyOS documentation: [http://www.tinyos.net/tinyos-2.x/doc/](http://www.tinyos.net/tinyos-2.x/doc/)
  - Resources on using TinyOS and motes: [http://www.tinyos.net/scoop/special/support](http://www.tinyos.net/scoop/special/support)

- Network simulators:
  - TOSSIM
  - ns-2
  - qualnet/glomosim
  - opnet
Project (contd.)

- **Timeline**
  - Select the topic and form your project group by 01/31/2009
  - Submit your detail project plan and timeline by 02/28/2009
  - Submit slides for your presentation at least one day before your presentation (date to be decided)
  - Submit your project report electronically by midnight 05/01/2009

- **Evaluation criteria**
  - Breadth and depth of your understanding of the problem, as evidenced by your project report and presentation
  - Presentation quality (e.g., clarity, readability, and conciseness) of your talk and written report
  - Whether or not you are able to stick to the project timeline
What is this course NOT for?

- Technology tutorial
  - Instead, we focus foundational issues
- Network programming
- Assemble networks with switches, routers, firewalls, etc.
- Design websites

- I do not really want to learn anything new, just want to get the credits and a good grade 😊
Policies

- Lecture attendance required

- Homework
  - No late submission without prior permission
  - No collaboration

- Frequently check out the course website for updated information

- Other university regulations apply
How to succeed in this course?

- Attend lectures
  - Look at the “big” screen, NOT the “small” computer monitor
- Read books
- Work on homework and project
- Ask questions!!!

Questions?
Student questionnaire

- Name (optional):
- E-mail (optional):
- Major:
- Degree/Expected Year:
- Previous coursework in computer networking:
- Previous coursework in probability theory, statistics, and mathematical logic:
- What do you expect to learn from this course? How do you think this course should be taught?
- How might this course contribute to your career objectives?