# CIS4930/6930 Advanced Topics on Mobile Networking
## Instructor: Prof. Ahmed Helmy

Website: cise.ufl.edu/~helmy (check the quick links and the teaching links)

Instructor: Prof. Ahmed Helmy, email: helmy@ufl.edu
- Office: CSE 426, Lab: CSE401 (Mobile Networking Lab)
- Instructor office hours: Thurs. 10:30am-12:30pm in CSE426.
  Jan 10 and 1st Thurs of every month thereafter: Thurs. 10:30-11:45am, and 1:15-2:00pm.
  [Note: office hours subject to change due to travel, faculty meetings, etc. Updates will be posted on the class/Prof. website reflect such change.]
- Class/Lecture meeting time/place: CSE222: Tuesday 8:30-10:25am, Thursday 9:35-10:25am.

- ***Goals/Objectives:***

The purpose of the course is to expose students to emerging networking protocols and technologies in the field of wireless mobile networks, with focus on Internet-of-Things (IoT) networking, mobility modeling and data analytics, connected vehicles, and mobile applications (apps). It also involves semester-long projects by groups of students to identify challenging problems in mobile networked applications and services through extensive reading and discussion, to propose solutions to those problems, then conduct high quality projects (through extensive simulations, analysis and implementation) to produce a term project report, and a mobile application that is the final product of their work.

More precisely, the objectives of this course are for the students:
- To acquire hands-on experience of wireless and mobile networking technologies. To experiment with state-of-the-art networking technologies and tools that enable students to diagnose and perform measurements on a mobile device or network.
- To get involved in projects on advanced topics in Internet-of-Things (IoT) as a general concept, including mobile ad hoc and sensor networks (MANets, VANETs, DTNs), and be able to present and write high quality technical reports on protocol design, analysis, simulation and implementation.
- To be part of a team and to tackle challenging problems in a semester-long project. To suggest solutions to these problems and to be able to demonstrate the feasibility and performance of the solution.
- To learn how to read and review publications in the wireless networking field from selected journal articles and conference proceedings.

- ***Course description:***

The overarching theme of this course is the systematic approach to understanding emerging mobile networking technologies, as pertains to measurement, analysis, mining, modeling, design and implementation of future mobile services and applications.

Topics covered: Emerging peer-to-peer and infrastructure-less mobile technologies, Internet of things (IoT), mobile device and smartphone measurements, mobility modeling, mobile social networks, data-driven modeling and design, mobile adhoc and sensor networks, adhoc and geographic routing, mobile resource discovery, trust and privacy, participatory/opportunistic sensing and mobile crowd sourcing, case studies for development of networked app services and its analysis, vehicular networks and opportunistic delay tolerant networking (DTN).

Major term project required.

Skills acquired in this class should emphasize and supplement deep understanding of protocol and network behavior. Students develop and enhance their understanding of the basics of wireless networking, mainly at the network layer and above, the behavior of the fundamental and evolving network protocols (e.g., ad hoc routing protocols, geographic routing, among others). Students also study that the network behavior is a collective behavior of all such protocols (and others), their interaction among themselves, and with the 'faulty' and dynamic network environment. By integrating network dynamics, such as packet losses, link/node failures and mobility, and through diagnostic and measurement tools, students study and analyze the effects of various network conditions on the overall behavior of the network.

Such deep practical understanding, along with strong analytical skills, are essential for future networking research and industry, that would greatly help in understanding today's networks, and designing networks of the future.

The lecture series starts by a set of lectures on fundamentals of mobile ad hoc networks, mobility models, wireless network measurements, network analysis and mining, data-driven modeling and design, trust and privacy, geographic routing, location based services, DTN routing, mobile resource discovery, mobile social networks, and hierarchical architectures for peer-to-peer mobile networks. This is followed by lectures on challenges and research directions in those fields, in addition to mobile platform programming and application development. During those initial weeks the students will form project and experiment groups, and every group gets to choose a topic to formulate a problem for the project. Also, each group is assigned a project presentation and demo slots. The weeks that follow cover specific topics and problems based on lists of readings (provided by the instructor and proposed by the students) and based on the projects progress. The last lecture of class usually includes slots for students to demo their projects and results.

*Project:* The term project has four main milestones: (1) an initial project proposal (~2 pages) due around the first ¼ of class, (2) a final project proposal (3~4 pages) due around the mid point of the semester, (3) an initial draft of the project report (~8 pages) due around the ¾ point of class, and (4) the final project report (~12 pages) due on the last lecture.

This course relies heavily on students' own effort and experimentation. It is a hands-on course where assignments and experiments are conducted by the students. The students are also involved in working in teams on a semester project.

- *Pre-requisites:*

In general, very good knowledge of fundamentals of computer networks is required. In addition, very good programming skills are also a requirement, along with knowledge of operating systems (e.g., Unix/Linux, Android). Knowledge of network simulation (e.g., using a network simulator such as *NS, Glomosim/QualNet, Sumo, ONE, VanetMobiSim, OpNet* or other) is a plus.

More specifically, the pre-requisite courses that *must* be taken (with good standing) before this course include: graduate level networking course.

- *Assignments and potential experiments:*

Students perform experiments around campus on measuring signal power strength, throughput, and delays of a wireless network using handheld PCs or laptops connected to base stations around the University of Florida campus.
The students also perform experiments for ad hoc routing in a multi-hop wireless network and experiments for a network of wireless sensor nodes and motes.

Examples of experiments/assignments may include (final set to be discussed in class):
- Drawing a wireless coverage (access points [APs]) map and measurements (cross validation through various measurement techniques, GPS, encounters, etc.)
- Encounter based networks (discovering devices, building ad hoc net, increasing the coverage of the wireless net, using static or mobile nodes, etc.)
- The 'socializer' experiments: establishing friendship and interest group links in mobile societies (through analysis of traces, mobile device experiments, surveys, etc.)
- Simulation of city sections using a vehicular mobility simulator.

The over-arching themes for the class for the project and experiments will be: - designing and analyzing future services through mobile apps networking for mobile social networking, transportation, location-based services, content sharing, mobile health, mobile education, and disaster relief or emergency management.

The experiments are carried out in groups of '2-4' students with combined reports. Each individual should understand and be able to perform the experiments on his/her own (there may be random pop quizes to test this ability). Students will also be required to design parts of new experiments. The students will also be asked to write reviews for papers that will be presented in class.

- Student responsibilities:
  - Attendance, class discussions, weekly reviews, paper readings
  - Participate in two presentations: topic presentation, project presentation
  - *High quality* final project report and demo
  - Team work, assignment and experiments evaluation

Instructions for the project proposal and report will be posted on the web in as much detail as possible. Similarly, instructions for performing experiments and samples of reviews will be posted.

The capacity of this course will be a *maximum* of 25 students, chosen mainly based on academic merit, and background preparation.

- Grading:Class participation (attendance, discussion) and 4 paper reviews (10%)
  Experiments and assignments (~3 experiments) (30%)
  Project and Presentations (60%):
    - Topic presentation (15%)
    - Project presentation & demo (15%)
    - Written Proposal, Report, Demo (30%)

- Readings/books:
  Optional (but not required) Book: Ad Hoc Networking, edited by Charles Perkins, Addison Wesley, 2001, ISBN 0-201-30976-9.

  Some related websites:
    - For updated links and news visit http://www.cise.ufl.edu/~helmy
    - The IMPORTANT mobility framework and mobility simulation tool [links through instructor's website].
    - MobiLib (Community-wide Library of Mobility and Wireless Networks Measurements): http://www.cise.ufl.edu/~helmy/MobiLib.htm
    - The VINT project; NS (Network Simulator) and NAM (Network Animator): http://www.isi.edu/nsnam/vint
    - The TVC and profile-cast websites through A. Helmy's website.

  Initial list of readings (to be updated every semester and during class as per the discussions and the student interest/input):  [to be updated through the website]
  [Note: Not all these papers are required. Required readings to be discussed in class.]

  - Unicast Adhoc routing :
  - DSDV: C. E. Perkins, P. Bhagwat, "Highly Dynamic Destination-Sequenced Distance Vector Routing for Mobile Computers", *ACM SIGCOMM CCR*, Oct. 1994.
  - DSR: D. B. Johnson, D. A. Maltz, "Dynamic Source Routing in Ad-Hoc Wireless Networks", *Mobile Computing*, 1996, pp.153-181.
  - AODV: C. E. Perkins, E. M. Royer, "Ad-hoc On-Demand Distance Vector Routing", 2nd *IEEE Workshop on Mobile Comp Systems and Applications*, Feb. 1999, p 90-100.
  - Comparison of unicast routing protocols in ad hoc networks: A. Iwata, C. Chiang, G. Pei, M. Gerla, T. Chen, "Scalable Routing Strategies for Ad Hoc Wireless Networks", IEEE *Journal on Selected Areas in Communications*, Vol. 17, No. 8, August 1999.

- ZRP: Z. Haas, M. Pearlman, "The Performance of Query Control Schemes for the Zone Routing Protocol", *ACM SIGCOMM* '98.
- ZRP: M. Pearlman, Z. Haas, "Determining the optimal configuration for the zone routing protocol", *IEEE JSAC*, p. 1395-1414, 8, Aug 1999.


- <u>Multicast Adhoc routing:</u>
- ODMRP: S. Lee, M. Gerla, C. Chiang, "On-demand multicast routing protocol", *IEEE WCNC, p.* 1298-1302, vol. 3, 1999.
- CAMP: J. J. Aceves, E. Madruga, "The Core-Assisted Mesh Protocol", *IEEE JSAC*, vol. 17, no. 8, pp. 1380-1394, August 1999.
- FGMP: C. Chiang, M. Gerla, L. Zhang, "Forwarding Group Multicast Protocol (FGMP) for Multihop, Mobile Wireless Networks", *ACM/Kluwer Journal of Cluster Computing*, vol. 1, no. 2, 1998.
- Comparison between multiple Multicast Ad Hoc protocols: S. Lee, W. Su, J. Hsu, M. Gerla, R. Bagrodia, "A Performance Comparison Study of Ad Hoc Wireless Multicast Protocols", *IEEE Infocom* 2000.


- <u>Broadcast Adhoc routing</u>:
- OLSR: T. Clausen, P. Jacquet, A. Laouiti, P. Muhlethaler, A. Qayyum et L. Viennot, "Optimized Link State Routing Protocol", *IEEE INMIC* 2001.
- Heuristics: S. Ni, Y. Tseng, Y. Chen and J. Sheu, "The Broadcast Storm Problem in a Mobile Ad Hoc Network", *ACM Mobicom*, 1999.
- Minimum dominating set (MDS): H. Lim, C. Kim, "Flooding in wireless ad hoc networks", *Computer Communications Journal*, 24(3-4),353-363, 2001.
- Multi-point relay (MPR): A. Laouiti, A. Qayyum et L. Viennot, "Multipoint Relaying: An efficient technique for flooding in mobile wireless networks", *HICSS*, 2002.
- Comparative analysis: Yunjung Yi, Mario Gerla, Taek-Jin Kwon, "Efficient Flooding in Ad hoc Networks: a Comparative Performance Study", *IEEE ICC 2003*.


- <u>Resource discovery and Rendezvous in MANets:</u>
- Grid: J. Li, J. Jannotti, D. Couto, D. Karger, R. Morris, "A Scalable Location Service for Geographic Ad Hoc Routing (GLS/Grid)", ACM Mobicom 2000.
- GHT: S. Ratnasamy, B. Karp, S. Shenker, D. Estrin, R. Govindan, L. Yin, F. Yu, Data-Centric Storage in Sensornets with GHT, A Geographic Hash Table, *ACM MONET,* 2003
- Jiangchuan Liu, Qian Zhang, Wenwu Zhu, Jun Zhang, and Bo Li, "A Novel Framework for QoS-Aware Resource Discovery in Mobile Ad Hoc Networks", *IEEE ICC,* 2002.
- Rendezvous Regions: A. Helmy, "Architectural Framework for Large-Scale Multicast in Mobile Ad Hoc Networks", *IEEE International Conference on Communications (ICC 2002),* April 2002.
- MARQ: A. Helmy, "Mobility-Assisted Resolution of Queries in Large-Scale Mobile Sensor Networks (*MARQ*)", *Computer Networks Journal - Elsevier Science (Special Issue on Wireless Sensor Networks)*, August 2003.

- CARD: A. Helmy, S. Garg, P. Pamu, N. Nahata, "Contact Based Architecture for Resource Discovery (*CARD*) in Large Scale MANets", *Third IEEE/ACM International Workshop on Wireless, Mobile and Ad Hoc Networks (WMAN), part of IEEE/ACM IPDPS 2003*, April 2003, Nice, France.
- TRANSFER: A. Helmy, "*TRANSFER*: Transactions Routing for Ad-hoc NetworkS with eFficient EneRgy", *IEEE GLOBECOM*, San Francisco, December 2003.


- Geographic routing in MANets:
- GPSR: B. Karp and H. T. Kung, "Greedy Perimeter Stateless Routing for Wireless Networks," *Proc. 6th Annual ACM/IEEE Int'l. Conf. Mobile comp. Net. (Mobicom)*,Boston, MA, Aug. 2000, pp.243-54.
- GOAFR: Fabian Kuhn, Roger Wattenhofer, Aaron Zollinger*,"*Worst-Case Optimal and Average-Case Efficient Geometric Ad-Hoc Routing", *ACM MobiHoc*, May 2003.
- A survey on position-based routing in mobile ad hoc networks Mauve, M. Widmer, A. Hartenstein, H. IEEE Network , Volume: 15 Issue: 6 , Nov/Dec 2001 Page(s): 30 -39
- LAR: Y. Ko, N. Vaidya, "Location-aided routing (LAR) in mobile ad hoc networks", Wireless Networks 6, 4, p. 307-321, July 2000.
- Geocast: Y. Ko, N. Vaidya, "Geocasting in mobile ad hoc networks: location-based multicast algorithms", IEEE WMCSA, p. 101-110, 1999.
- J. Navas, T. Imielinski, "GeoCast - Geographic Addressing and Routing", *MobiCom* 97.
- EASE: M. Grossglauser, M. Vetterli, "Locating Nodes with EASE: Last Encounter Routing for Ad Hoc Networks through Mobility Diffusion", *IEEE INFOCOM 03*, San Francisco, March 2003.
- FRESH: H. Dubois-Ferrière, M. Grossglauser, M. Vetterli, "Age Matters: Efficient Route Discovery in Mobile Ad Hoc Networks Using Encounter Ages", *ACM MOBIHOC 03* , Maryland, June 2003.
- Terminodes: L. Blazevic, L. Buttyan, S. Capkun, S. Giordano, J. Hubaux, and J. Le Boudec. Self-organization in mobile ad-hoc networks: the approach of terminodes, *IEEE Communications Magazine*, 2001.
- Terminodes: Ljubica Blazevic, Silvia Giordano, Jean-Yves Le Boudec. Anchored Path Discovery in Terminode Routing. *Networking* 2002: 141-153.


- Mobility modeling and simulation:
- T. Camp, J. Boleng, and V. Davies, "A Survey of Mobility Models for Ad Hoc Network Research", *Wireless Communication & Mobile Computing (WCMC): Special issue on Mobile Ad Hoc Networking: Research, Trends and Applications,* vol. 2, no. 5, pp. 483-502, 2002. /
- X. Hong, M. Gerla, G. Pei, and C.-C. Chiang, "A Group Mobility Model for Ad Hoc Wireless Networks", *Proceedings of ACM/IEEE MSWiM'99,* Seattle, WA, Aug. 1999.

- X. Hong, T. Kwon, M. Gerla, D. Gu and G. Pei, "A Mobility Framework for Ad Hoc Wireless Networks", *Proceedings of ACM Second International Conference on Mobile Data Management (MDM '2001),* Hong Kong, Jan. 2001.
- Christian Bettstetter, "Mobility Modeling in Wireless Networks: Categorization, Smooth Movement, and Border Effects", *ACM Mobile Computing and Communications Review*, vol. 5, no. 3, pp. 55-67, July 2001.
- M. Grossglauser and D. Tse, "Mobility Increases the Capacity of Ad Hoc Wireless Networks", *IEEE/ACM Trans. on Networking*, vol 10, no 4, August 2002. (Conf version: M. Grossglauser and D. Tse, "Mobility Increases the Capacity of Ad Hoc Wireless Networks", *IEEE INFOCOM*, Anchorage, Alaska, April 2001)
- InfoStation: D.J.Goodman, J.Borras, N.B.Mandayam, and R.D. Yates "INFOSTATIONS:A New System for Data and Messaging Services", *Proceedings of IEEE VTC* '97, 2 , 1997, pp.969-973.
- S. Diggavi, M. Grossglauser, D. Tse, "Even One-Dimensional Mobility Increases Ad Hoc Wireless Capacity", *ISIT 02*, Lausanne, Switzerland, June 2002.
- IMPORTANT: F. Bai, N. Sadagopan, A. Helmy, "The IMPORTANT Framework for Analyzing the Impact of Mobility on Performance of Routing for Ad Hoc Networks", *AdHoc Networks Journal - Elsevier Science*, August 2003. (Conf. version: F. Bai, N. Sadagopan, A. Helmy, " IMPORTANT: A framework to systematically analyze the Impact of Mobility on Performance of RouTing protocols for Adhoc NeTworks", *IEEE INFOCOM (The 22nd Annual Joint Conference of the IEEE Computer and Communications Societies)*, March/April 2003, San Francisco.)
- PATHS: N. Sadagopan, F. Bai, B. Krishnamachari, A. Helmy, " PATHS: analysis of PATH duration Statistics and their impact on reactive MANET routing protocols", *ACM MobiHoc (The Fourth ACM International Symposium on Mobile Ad Hoc Networking and Computing)*, June 2003.

- MAC protocols for wireless networks:
- PAMAS: C. S. Raghavendra, Suresh Singh, "PAMAS -- Power Aware Multi-Access protocol with Signaling for Ad Hoc Networks," *Computer Communication Review,* July 1998.
- MACAW: Vaduvur Bharghavan, Alan Demers, Scott Shenker, Lixia Zhang, "MACAW: A Media Access Protocol for Wireless LAN's", *ACM SIGCOMM*, 1994.
- MACA: Chunhung Richard Lin and Mario Gerla , "MACA/PR: An Asynchronous Multimedia Multihop Wireless Network", In Proceedings of *IEEE INFOCOM*, 1997.
- MACA: F. Talucci, M. Gerla, and L. Fratta , "MACA-BI (MACA by invitation)-A Receiver Oriented Access Protocol for Wireless Multihop Networks", In Proceedings of *IEEE PIMRC*, 1997.
- SMAC: Wei Ye, John Heidemann and Deborah Estrin, "An Energy-Efficient MAC Protocol for Wireless Sensor Networks", *In Proceedings of the 21st International Annual Joint Conference of the IEEE Computer and Communications Societies (INFOCOM 2002),* New York, NY, USA, June, 2002.

- IP Mobility Support protocols, and micro-mobility:
- Mobile IP: C. Perkins, "IP Mobility Support", RFC 2002, Internet Engineering Task Force, October 1996.
- MIPv6: C. Perkins and D. Johnson, "Mobility Support in IPv6", Proceedings of MobiCom'96, November 1996.
- Hawaii: R. Ramjee, T. La Porta, L. Salgarelli, S. Thuel, K. Varadhan, L. Li, "IP-based access network infrastructure for next-generation wireless data networks", IEEE Personal Communications , Volume: 7 Issue: 4 , Page(s): 34 -41, Aug. 2000.
- Cellular IP: A. Campbell, J. Gomez, S. Kim, A. Valko, C. Wan, Z. Turanyi, "Design, implementation, and evaluation of cellular IP" IEEE Personal Communications , Volume: 7 Issue: 4 , Page(s): 42 -49, Aug. 2000.
- M&M: A. Helmy, M. Jaseemuddin, G. Bhaskara, "Multicast-based Mobility: A Novel Architecture for Efficient Micro-Mobility", *IEEE Journal of Selected areas in Communications (JSAC),* Sept 2003.
- M&M A. Helmy, "A Multicast-based Protocol for IP Mobility Support", *ACM SIGCOMM Second International Workshop on Networked Group Communication (NGC 2000), Palo Alto,* November 2000.

- ***Note:***
  - - Starting summer 09 UFL has introduced the '-' in the letter grades (A-, B-, C-, D-) in addition to the previous ones.  Please visit the following website for more information:
  - http://www.registrar.ufl.edu/catalog/policies/regulationgrades.html
  - 
  - - For more information on grades and grading policies, please visit:
  -  "https://catalog.ufl.edu/ugrad/current/regulations/info/grades.aspx"
  - - Honesty Policy – All students admitted to the University of Florida have signed a statement of academic honesty committing themselves to be honest in all academic work and understanding that failure to comply with this commitment will result in disciplinary action. This statement is a reminder to uphold your obligation as a UF student and to be honest in all work submitted and exams taken in this course and all others.
  - - Accommodation for Students with Disabilities – Students Requesting classroom accommodation must first register with the Dean of Students Office.  That office will provide the student with documentation that he/she must provide to the course instructor when requesting accommodation.
  - 
  - - UF Counseling Services –Resources are available on-campus for students having personal problems or lacking clear career and academic goals.  The resources include:
  - ·	UF Counseling & Wellness Center, 3190 Radio Rd, 392-1575, psychological and psychiatric services.
  - ·	Career Resource Center, Reitz Union, 392-1601, career and job search services.

- - Software Use – All faculty, staff and student of the University are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against University policies and rules, disciplinary action will be taken as appropriate. We, the members of the University of Florida community, pledge to uphold ourselves and our peers to the highest standards of honesty and integrity.