High-Performance Networking
University of Kansas EECS 881
Fall 2012

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http://www.ittc.ku.edu/~jpgs/courses/hsnets
High-Performance Networking

AE.1 Administrivia

AE.1.1 Schedule
AE.1.2 Prerequisites and description
AE.1.3 Instructor information and correspondence
AE.1.4 Grading and student expectations

AE.2 Ethics and academic integrity

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High-Performance Networking

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Course Information
High-Level Schedule

• Lecture: Mon. 18:10 – 21:00
  - 3150 Learned Lawrence Campus
  - 251 Regnier Edwards Campus (remote video link)

• Discussion: Wed. 18:10 – 21:00
  - meets only as needed
    • ONL tutorial and laboratory sessions
    • rescheduled lectures

• 20 Aug. – 16 Dec.
  - three sectional exams plus final (10 Dec.)
  - no class 03 Sep. (Labor Day) and 08 Oct. (fall break)
  - occasionally rescheduled to discussion slot due to travel
Course Information
Cancellation and Rescheduling

• Cancellation due to weather
  - official closings unlikely
    • follow media announcements
  - if I can’t make it from Lawrence
    • email and Facebook update to class list by 15:00

• Rescheduling due to my travel
  - I try very hard to avoid rescheduling class
  - project meetings & conferences sometimes interfere
  - this is the cost of an instructor who is active in research
  - rescheduled lectures held Wed.
High-Performance Networking

AE.1.2 Prerequisites and Description

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High-Performance Networking
EECS 881 Prerequisites

• You **must** have networking background at least one of:
  - KU EECS 780 Communication Networks
    • [www.ittc.ku.edu/~jpgs/courses/nets](http://www.ittc.ku.edu/~jpgs/courses/nets)
  - KU EECS 563 | 663 Introduction to Communication Networks
  - introductory networking class elsewhere
    • Kurose, Leon-Garcia, Stallings, Tanenbaum, Peterson, etc.
  - significant experience
    • you must convince me you are comfortable with 780 material
    • talk to me after class if you intend to invoke this option
Networking Courses

Core Courses

• EECS 780: Communication Networks
  spring at Edwards
  - prerequisite for...
  - only one of {EECS 563 | EECS 663 | EECS 780} for credit
    • prerequisite for...

• EECS 881: High-Performance Networking
  fall in even numbered years at Edwards

• EECS 882: Mobile and Wireless Networking
  fall in odd numbered years at Edwards

• EECS 712: Network Security
Networking Courses

Selected Additional Courses

- EECS 563: Introduction to Communication Networks
  *fall in Lawrence*
- EECS 766: Resource Sharing for Broadband Access Networks
- EECS 745: Implementation of Networks
- EECS 864: Multiwavelength Optical Networks
- EECS 888: Internet Routing Architectures
- EECS 983: Resilient and Survivable Networking
  *spring in even numbered years Lawrence*
Communication Courses

Selected Communications Courses

- EECS 861: Random Signals and Noise
- EECS 862: Digital Communication Systems
- EECS 863: Analysis of Comm. Networks
- EECS 865: Wireless Communication Systems
- EECS 869: Error Control Coding
- EECS 964: Simulation of Comm. Systems
- EECS 965: Detection and Estimation Theory
- EECS 967: Mathematical Optimization with Communications Applications
- EECS 969: Information Theory
Comprehensive coverage of the discipline of high-bandwidth low-latency networks and communication, including high bandwidth\(\times\)delay products, with an emphasis on principles, architecture, protocols, and system design. Topics include high-performance network architecture, control, and signalling; high-speed wired, optical, and wireless links; fast packet, IP, and optical switching; IP lookup, classification, and scheduling; network processors, end system design and protocol optimization, network interfaces; storage networks; end-to-end protocols, mechanisms, and optimizations; and high-bandwidth low-latency applications. Principles will be illustrated with many leading-edge and emerging protocols and architectures.

Prerequisite: EECS 780, 563, or equivalent
High-Performance Networking
AE.1.3 Instructor Information, Correspondence

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Instructor Information

Background

• Dr. James P.G. Sterbenz
  - current positions
    • Associate Professor, KU Lawrence, US
    • Visiting Professor of Computing, Lancaster University, UK
  - past research and management positions
    • UMass, BBN Technologies, GTE Laboratories, IBM Research
  - academic background
    • D.Sc., Washington University in St. Louis, 1991
  - research interests
    • resilient and survivable networking
    • autonomic, programmable, and active networks
    • mobile wireless networking
    • high-speed networking and system architecture
Instructor Information

Contact Modes

- **Web:** check the class Web pages first
  - important announcements at top of 2010 page
  - detailed schedule
- **Email:** generally the best means of communication
  - many issues and questions can be quickly resolved
  - use to arrange other appointments
- **Facebook and Google+:**
  - KU EECS 881 group
  - [http://www.facebook.com/groups/EECS881](http://www.facebook.com/groups/EECS881)
  - [http://plus.google.com/110278051580845123615](http://plus.google.com/110278051580845123615)
  - optional: subscribe if you wish
Instructor Information

Contact Modes

- Interactive
  - skype chat (but not voice unless pre-negotiated)
    - jpgsterbenz
  - phone

- Office hours
  - face-to-face contact
Instructor Information

Office Hours

- Thu. 17:00 – 18:00
  - unless advised otherwise due to meetings or travel
- 154 Nichols (my office)
- Or by appointment
  - email, chat, or call to arrange in advance
  - chat or call before dropping in unless already on campus
Instructor Information
Contact: Email Address

- Email: jpgs@eecs.ku.edu
  only
  - begin subject with exact string “EECS881 -”
    • email to other addresses will likely be misfiltered and unread
    • no space between EECS and 881
  - I generally check email daily
    • email is unreliable; retry if no reply within 48 hours
    • if quick reply is needed feel free to skype chat or phone
Instructor Information

Contact: Email Address

- Email with *meaningful* subject lines
  - bad
    - Subject: Hi!
    - Subject: regarding class
  - good
    - Subject: EECS881 - need help understanding BIC
Electronic Mail

Netiquette: Sender Identification Name

• Configure email client with your *name* in ISO-Latin
  - e.g. Ima K.U. Student <ima.student@eecs.ku.edu>

• CJK (Chinese, Japanese, Korean) encodings
  - appear as gibberish to older and non-GUI email clients
  - use only *after* ISO-Latin name
  - e.g. James P.G. Sterbenz 司徒傑莫 <jpgs@eecs.ku.edu>
Electronic Mail

Netiquette: Sender Identification Signature

- Define a meaningful signature (.sig)
  - name, affiliation, telephone number, URL if you have one
  - max. of 4 lines (not including separator dashes)
  - max of 72 characters/line, e.g.

Ima K.U. Student
Electrical Engineering & Computer Science, The University of Kansas
ima.student@eecs.ku.edu www.ittc.ku.edu/~ikus
+1 785 864 4776
Electronic Mail
Netiquette: Formatting

• Email was originally text-only with no formatting
  - many people still like it that way!
    • some people still use text only clients
    • increasing use of PDAs
  - not all clients are MS Outlook!

• Unless pre-negotiated with the recipient:
  - use plain text with no formatting
    • some email clients have formatting on by default
    • some misconfigured (MS-Exchange) servers format anyway
  - do not send email as HTML
  - do not embed images
Electronic Mail
Netiquette: Content and Attachments

• Content issues
  - use meaningful subject lines
  - spellcheck (most modern clients do this)
  - *think* before you send

• Simple emails should not be sent as attachments
  - e.g. MS-Word document containing “where are you now?”

• Do not send very large attachments unless
  - receiver is able to handle them (broadband access)
  - small enough to pass relay & server limits (typ. <10 MB)
Electronic Mail
Netiquette: Professionalism

• Email is like conversation, writing, and attire
  – adapt style to context
  – academic and professional is more formal than with friends

• Style
  – plain text, no embedded images
  – limit jargon and emoticons to someone you know well
  – proofread and think before you send

• Proofread and *think before you send!*
Electronic Mail

Netiquette: Professionalism

- Avoid free email accounts
  - e.g. hotmail, yahoo
- Gives you a very unprofessional appearance
  - frequently auto-append advertisements
- Frequently spam-blocked
- Use academic or corporate email addresses
  - for professional correspondence
Electronic Mail
Netiquette: Professionalism Examples

To: James Sterbenz <jpgs@eecs.ku.edu>
From: Ima <kewl_dude@stupidmail.com>
Subject: need a job!!!

i'm new at KU and really like it 😊
i'm interested in everything and
am bombing this email to all KU
professors. I've stopped by your office
in Eaton but you're never there!!! 😐
do you even have office hours
dude? LOL! Just tell me when I can
drop by too learn what you do
r u t h e r e ???!!

cu later,
ima

Get your free email at Stupidmail.com!

Eat at Joe's: 1234 Mass. Lawrence, KS

What's wrong?
Electronic Mail
Netiquette: Professionalism Examples

To: James Sterbenz <jpgs@eecs.ku.edu>
From: Ima <kewl_dude@stupidmail.com>
Subject: need a job!!!

i’m new at KU and realy like it 😊
i’m interested in everything and am bombing this email to all KU professors. i’ve stopped by your office in Eaton but your never there!!! 😊
do you even have office hours dude? LOL! Just tell me when I can drop by too learn what you do r u t h e r e ???!!

cu later,
ima

_______________
Get your free email at Stupidmail.com!

Eat at Joe’s: 1234 Mass. Lawrence, KS

To: James Sterbenz <jpgs@eecs.ku.edu>
From: Ima Student <student@eecs.ku.edu>
Subject: Interest in ResiliNets group

Dear Professor Sterbenz,

I am a new M.S. student in the EECS department with interests in networking. I have looked at your Web pages and read the SUMOWIN paper. I am very interested in this research and will come to the next ResiliNets group meeting on Friday. I would like to discuss the possibility of you becoming my advisor and want to understand if there are any funding opportunities.

Sincerely,
Ima Student

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Ima Student       EECS, Univ. of Kansas
student@eecs.ku.edu     +1 785 555 1212
Student Information

Introductions

• Brief Introductions around the room
  – say who you are and why you are here
• Photos to help me learn your names
Student Information
Contact and Background

- Roster information to be filled in pass-around sheet
  - full name, nickname
  - employer if not full-time student
  - email for class distribution list
    - preferred and mandatory .ku.edu address
  - phone numbers will only be used for urgent matters
    - day and evening
  - degree (BS, MS, PhD)
    - major (CS, CoE, EE, IT)
      - focus area if MSIT (Internet Engr., Info. Sec., Software Engr.)
    - option if MS (course, project, thesis)
    - advisor name (“none” if you don’t have one yet)
Course Information
Correspondence to Class

- Course information and notes
  - http://www.ittc.ku.edu/~jgps/courses/hsnets
    - notes for each lecture will be posted in PDF
      - check for 2010 date and version on first page
    - navigate to subpage for Fall 2010 specific information
      - schedule and deadlines
  - http://www.ittc.ku.edu/~jgps/courses
    - generic information
  - check *regularly* for updates
    - readings and assignments in schedule table in sub-page
    - “last updated” on bottom of page
Course Information
Correspondence to Class

• Class email list
  - all students are *required* by EECS to use `.ku.edu` email
    • I’m willing to use other email addresses…
    • …but only if they are relatively reliable
      - many free email accounts are not!
      - if there are problems I’ll change your entry to a `.ku.edu` address
    - check email regularly
    - check email every afternoon before class

• Telephone
  - I’ll only phone you if *urgent*
Instructor Information
Contact: Phone and Chat

• Contact information
  - phone
    • Edwards office: +1 913 897 8538
    • Lawrence Nichols office: +1 785 864 7890
    • Lawrence Eaton office: +1 785 864 8846
    • only if urgent (consider Δtime) +1 508 944 3067
    • don’t call me at home unless emergency
  - skype: jpgsterbenz
    • ok to use chat judiciously when email not appropriate
      - send meaningful introduction message!
    • don’t use voice unless prearranged by chat
      - I frequently am not in a position to use headset/microphone
High-Performance Networking

AE.1.4 Grading and Student Expectations

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AE.3 Course outline
Course Information

Importance of Reading

• How hard is this class?
  - not a “killer class” in terms of homework and projects
  - but it is intellectually challenging with significant reading

• Required readings are *mandatory*
  - the textbooks are not just a reference
  - you won’t be able to use it on exams

• Reading *must* be done *before* corresponding class
  - you are *doomed* if you get behind on the reading
  - you are responsible for *all* required reading
    • may be on exams *even if not covered in lecture*
    • contributes to your class participation grade
Course Information

Textbooks

• Required textbooks
  - Sterbenz & Touch: *High-Speed Networking*
    • also used in EECS 780
  - Comer: *Network Systems Design using Network Processors, Intel 2xxx*

• Recommended textbooks
  - Welzl: *Network Congestion Control*
  - some required, many optional readings; may wish to own

• Background textbook
    • used in EECS 780; consult if your networking background weak
Course Information

Additional Reading

- Additional required papers
  - selected papers to supplement textbooks, e.g.
    - lookup and classification
    - TCP enhancements and protocol offloading
- Student paper presentations
  - each student will select papers to present
    - beginning the third week, one/week
    - pick an area of interest from the books and course table
    - choose paper in table or suggest alternative
  - all students must read before the class presented
    - part of the class participation grade
Course Information
Grades

• Grades: modified curve grouped by mode
  - based only on merit; not on:
    • employer reimbursement or lack thereof
    • immigration status or potential visa invalidation
    • probationary status at KU
  - qualitative meaning
    A: exceptional exam results and outstanding term paper
    B: mastery of material and solid project or term paper
      this is the basic expectation for a graduate student
    C: slacking; know basic material or marginal project/paper
    D: very poor performance on exams or project/paper
    F: nonperformance on exams or paper
      academic misconduct regardless of other grades
Course Information

Grade Contribution

- Relative grade contribution
  - 30% section exams
    - two at 10% each
    - third at 10% will be first half of final exam period
  - 10% comprehensive portion of final exam
  - 25% project or term paper
    - significant extra credit for publishable paper
  - 15% lab exercises and homework
  - 20% paper presentation and class participation
    - brownie points contribute to this part of the grade
  - mandatory academic integrity quiz in second class
    - must be made up if you miss this class
Course Information

Exam Schedule and Weight

• Section exams: 30%
  - tentative schedule *subject to change*
    • academic integrity quiz on 05 Sep. (required to pass course)
    • exam 1 on 01 Oct. (I will be out of the country)
    • exam 2 on 12 Nov.
    • exam 3 on 10 Dec. (portion of final exam period)

• Final exam: 10%
  • final exam on 10 Dec.
  • comprehensive covering entire course
  • synthesis of multiple sections
  • portion of final exam period
Course Information

Exam Characteristics

• Closed book, no electronic devices
  - notify me *in advance* if you know you must miss
  - you will probably have to take the exam in advance

• Exams test *understanding of concepts*
  - not memorisation of facts that could be looked up
  - not focused on the ability to solve problems
  - this will be new to some of you!

• More exam information on
  [http://www.ittc.ku.edu/~jpgs/courses/exams.html](http://www.ittc.ku.edu/~jpgs/courses/exams.html)
Course Information

Exam Questions

• Exams consist of two types of questions
  - sufficient space given to properly and fully answer

• Short answer example (several per page):
  - example question:
    Compare the functionality of the link and transport layers.
Course Information

Exam Questions

• Exams consist of two types of questions
  - sufficient space given to properly and fully answer

• Short answer (several per page):
  - example question:
    Compare the functionality of the link and transport layers.

• Long answer (one per page):
  - example question:
    Sketch and label a packet flow diagram for stop-and-wait, go-back-n, and selective repeat. Explain the advantages and disadvantages of each scheme.
Course Information

Exam Answers

- Answers must legibly fit in space provided
  - sufficient space given to properly and fully answer
  - be brief; points will be deducted for irrelevant information
    - and you will have a hard time finishing the exam
  - writing on back of page & deep into margins will be ignored
Course Information

Exam Answers: How to Answer

• Example question:
  Compare the functionality of the link and transport layers.
Course Information
Exam Answers: How to Answer

• Example question:
  
  Compare the functionality of the link and transport layers.

  - example correct answer (1 minute to write):
    Both the link and transport layer transfer data; the link layer hop-by-hop and the transport layer end-to-end.
Course Information
Exam Answers: How Not to Answer

Example question:

Compare the functionality of the link and transport layers.

- example correct answer (1 minute to write):
  Both the link and transport layer transfer data; the link layer hop-by-hop and the transport layer end-to-end.

- example poor answer (10 minutes to write):
  The link layer is layer 2 in the OSI model, shown in the figure. Examples of link layer protocols include Ethernet, 802.11, SONET, and HDLC. 802.11 was developed in as a replacement for Ethernet, and thus has similar frame structure, shown in Figure 2. Note that 802.11 has more MAC address fields than Ethernet. The reason for the additional address fields has to do with the operation of the 802.11 MAC. Actually I really don’t know the answer to this question, but I did memorise a bunch of stuff on some of these protocols, so I hope that if I write enough that I will get some credit for this question and that if I bomb you with information you will find some reason to give me credit on this problem and so I'm just going to keep writing until time is called on this
Course Information
Lab and Homework Assignments

• 15% of grade on ONL labs and occasional homework
• You **must** solve assignments individually
  - you may discuss problems and solution strategies
  - unless group lab projects explicitly assigned
• Due at the beginning of class on the due date
  - usually Fri. – late assignments generally *not* accepted
    • unless prearranged, e.g. due to illness or business travel
• Submit by email to the instructor:
  - **Subject:** line *must* begin with the *exact string* "EECS881 - assignment"
    • homework as inline text or MIME attachment in PDF
Course Information
Open Network Laboratory Accounts

• ONL: Open Network Laboratory
  - remote access to switches with network processors

• Get an account now
  - use Web browser to open: onl.arl.wustl.edu
  - click on: Get an account
  - choose project name: ku881f12

• Begin to read NPR tutorial
  - we will use the NPR rather than the NSP
Course Information
Project or Term Paper

• 25% of grade based on project or term paper

• Purpose and scope:
  - research area of communication networks beyond class
  - technical in nature
    • may lead to MS thesis or PhD dissertation
    • should lead to publication
  - either a
    • based on an implementation or simulation project
    • significant paper survey
  - gain technical writing and presentation experience

• Submission requirements and templates at
  www.ittc.ku.edu/~jgps/courses/writing-guide.html
## Course Information

### Project Milestones and Tentative Schedule

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Details</th>
<th>Due date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two ideas</td>
<td>2 ideas with 2 <em>complete</em> references each</td>
<td>21 Sep.</td>
</tr>
<tr>
<td>Proposal</td>
<td>Proposal with 5 <em>complete</em> references</td>
<td>08 Oct.</td>
</tr>
<tr>
<td>Outline</td>
<td>Draft outline with <em>no</em> body text and more refs.</td>
<td>09 Oct.</td>
</tr>
<tr>
<td>Draft paper</td>
<td>Mostly complete draft report or paper</td>
<td>23 Nov.</td>
</tr>
<tr>
<td>Presentation</td>
<td>Presentation to class and discussion</td>
<td>05 Dec.</td>
</tr>
<tr>
<td>Final paper</td>
<td>Complete polished report or paper</td>
<td>07 Dec.</td>
</tr>
</tbody>
</table>

- **Series of milestones: *stick to them!***
  - flow control process and allow us to discuss progress
    - you will not do well if you wait until the last minute
  - timely submission part of final paper grade
  - milestones not meeting basic requirements not accepted
Course Information
Sources of Literature: Library

• The Library
  - big building with books and paper journals: use it!

• Physically browsing is a wonderful way to brainstorm
  - Spahr Engineering Lib. TK numbers most relevant
  - Anschutz (science) Lib. QA and QC numbers most relevant
  - Edwards Library very small collection

• Online resources at www.ku.edu/libraries
  - selected journals
  - access to archived books and journals
  - interlibrary loan
Course Information

Sources of Literature: Web

• The Web
  - source for conference and journal papers
    • ACM Digital Library, IEEE, LNCS (subscription through library)
    • individual and project Web pages
  - source for information on research projects
  - source for other information
    • wikipedia: incredibly useful as \textit{launching point} to other work
      - rarely appropriate to cite wikipedia pages
    • non-refereed reports and information
  - compare to a street corner bulletin board: \textit{use with care}
  - use Web citations \textit{very} judiciously
    • reports with many URL refs will not get an acceptable grade!
Course Information

Class Participation

• 20% of grade based on presentation & participation
  - insightful questions and comments on lectures
  - evidence that reading has been done *before* lecture
  - brownie points
    • find bug in lecture note or book; make a good suggestion
    • email reminder with *exact* Subject: EECS780 - Brownie Point

• Interactive class is better for all of us
  - questions, comments, arguments
  - blurt it out; don’t wait: you don’t need to raise your hand
  - this may be a cultural shift for some of you; get used to it

• Reminder: reading *before* class essential
Course Information
Reading Presentations

• Each student will choose and present 1 or 2 papers
  - beginning the third week
  - significant part of 15% participation grade

• Each student will choose 1 topic from course table
  - identify relevant paper
  - prepare presentation
  • due in PowerPoint evening before presentation
  • email with exact Subject: EECS780 - Presentation

• All students must read paper before class
  - papers will be listed in readings table
  - questions contribute to class participation grade
Course Information

Etiquette

• Try to be on time
  – I understand that we are all commuting, but…
  – consistent late arrivals are disruptive

• Inform me in advance if you need to miss class
  – we accommodate working professionals
  – we’ll arrange to make up missed material

• No audible mobile phone or pagers
  – if it doesn’t vibrate, turn it off!

• University does not tolerate class disruption
  – protests, sit-ins, heckling, etc. (I guess)
Communication Networks

AE.2 Ethics and Academic Integrity

AE.1 Administrivia
AE.2 Ethics and academic integrity
AE.3 Course outline
Academic Integrity and Plagiarism

Reading the Riot Act

• Apologies to those that already know this
  – … especially who’ve heard it from me before
• Opportunity to learn for those who:
  – are inexperienced in writing
  – come from an environment or culture of tolerance
• Warning of the consequences
  – ignorance will not be an excuse
  – ask me if you have any question about this
• Applies to
  – copying homework and lab exercises
  – cheating on exams
  – plagiarism on term paper and presentation
Academic Integrity and Plagiarism
Referencing and Citations

• All sources **must** be properly referenced and cited
  - authors, “paper name”, *journal*, date, publisher, page-range
    • also URL if from obscure source (e.g. university tech reports)
    • see course Web page or for examples


• Cite whenever
  - work is related or ideas are used
  - text is quoted or paraphrased
  - diagrams are reproduced or incorporated (even if redrawn)
Academic Integrity and Plagiarism
Proper Quoting and Paraphrasing

• Quoting text or paraphrasing
  – “quotation marks” for sentence or less
  – blockquote for multiple sentences

• Beware of read-then-write in two windows
  – *never ever* cut-and-paste
  – take intermediate notes from which you write
Academic Integrity and Plagiarism

Excessive Quoting and Paraphrasing

• Quoting is *rarely* needed
  - example: quoting or paraphrasing definition or principle

• Sequence of quotes *doesn’t* show understanding
  - not a shortcut to English writing skills
    • better to be in your *own* imperfect English
  - papers with excessive quotes will not receive decent grade
    • even if properly quoted
Academic Integrity and Plagiarism
Detection and Sanctions

• Plagiarism is remarkably easy for me to detect
  - inconsistent writing styles and language use
  - technical depth beyond the supposed author
  - inconsistent terminology

• Tools: Web makes both plagiarism & detection easier
  • Google on suspicious phrases
  • automated tools match and highlight with fuzzy searches

• Plagiarism will result in F for course
  - and possible further sanctions
  - it is highly unlikely that you will get away with it!
  • but students still try every semester; you have been warned
Academic Integrity and Plagiarism

Academic Integrity Quiz

• Homework this week: read
  http://www.ittc.ku.edu/~jpgs/courses/academic-integrity.html
  http://www.ittc.ku.edu/~jpgs/courses/source-cite.html

• You *must understand* this material
  - ask me if you have *any* question
  - goal is for new students to learn

• Next week: academic integrity quiz
High-Performance Networking

AE.3 Course Outline

AE.1 Administrivia
AE.2 Ethics and academic integrity
AE.3 Course outline
   I. Principles, network architecture and control
   II. Lower layers and network components
   III. Upper layers and domain-specific networks
EECS 881 Outline

I: Principles, Network Architecture and Control

I: Principles, network architecture and control
   PP: Preliminaries and principles
   AT: Architecture and topology
   CS: Control and Signaling
   LL: Links, LANs, and optical networks

II: Lower layers and network components

III: Upper layers and domain-specific networks
EECS 881 Outline

II: Lower Layers and Network Components

I: Principles, network architecture and control

II: Lower layers and network components
   NP: Network processors
   SR: Switches and routers
   IO: Switch I/O: lookup, classification, and scheduling
   ES: End systems and network interfaces

III: Upper layers and domain-specific networks
EECS 881 Outline

III: Upper Layers and Domain-Specific Nets

I: Principles, network architecture and control
II: Lower layers and network components
III: Upper layers and domain-specific networks
   TL: End-to-end transport
   NA: Networked applications
   SC: Storage networks, data centers, and grid computing
   FO: Future outlook