**EE 382N: Distributed Systems** **Fall 2017**

# Lecture 1: August 31

*Lecturer: Vijay Garg* *Scribe: Asad Malik*

## Introduction

Students in EE 382N are required to scribe lecture notes for one lecture. These lecture notes will be done using the document processing system called Latex. There is a sample *scribe.tex* file on the Canvas system which can be used as a template. You can run `pdflatex` on that file to generate *scribe.pdf*.

During each class, the professor will list the topics to be covered on the whiteboard. Once a topic has been completed, he will check it off the list. That's the time to ask questions.

**Textbook**: Elements of Distributed Computing

The textbook will cover roughly 50% of the course material. The rest will be covered by lectures and research papers. There will be 3 tests during the semester and **no** final exam. Test dates will be posted on canvas.

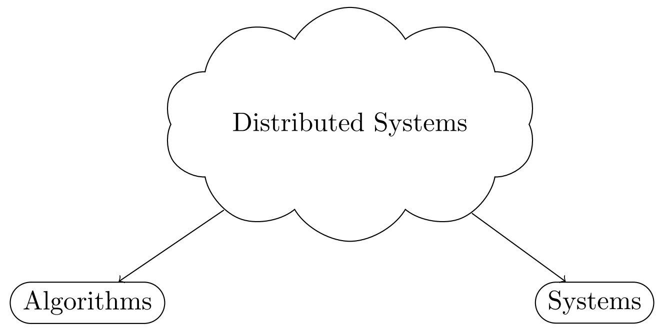
### Course Rules

- No cellphone or laptop use allowed during the lecture
- Tablets are permitted for the sole purpose of taking lecture notes
- Ask at least one question during the semester
- Limit yourself to 5 questions during a lecture
- No guns allowed in the office

### Course Info

- Prof. Garg Office: EER 7.884
- TA: Changyong Hu (colinhu9@gmail.com)
- Assignments done in groups of 2
- Term project done in teams of 3-4

## Goals of the Course




Both **Algorithms** and **Systems** are an important part of this course. We will be covering the theory as well as putting it into practice so expect to work on complex programming assigments.

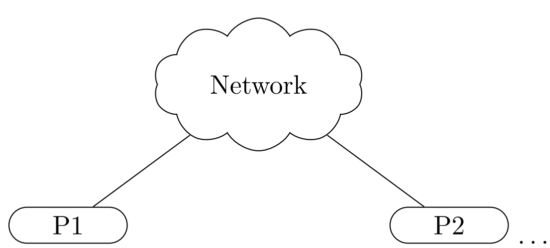
The term project is a very important part of the course. The goal is to produce something new instead of working on already solved problems. The term project is loosely based on a conference style of submission with each team submitting a paper (7-8 pages) which will be reviewed by their peers. Papers which are accepted by the reviewers will be presented at the end of the semester. The deadline for submission will be 2-3 weeks prior to the end of the semester (exact dates are TBD). You will be expected to study and work in groups as collaboration is a good way to learn the material.

## Happened-before, Posets & Lattices

**Source**: Lamport's paper '78 *T*ime, Clocks, and the Ordering of Events in a Distributed System

**Definition** of Distributed Systems. There are 3 assumptions associated with what a distributed system is:

1. No shared clocks
2. No shared memory
3. Asynchronous




The only way for communication is through messages which may take an unbounded amount of time. There is no way to synchronize the clocks due to uncertainity of how long messages might take.

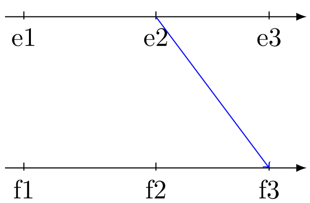
Lamport's paper discusses how to order events with asynchronous clocks.

Defining happened-before $(\rightarrow)$ without using clocks:

If we say e $\rightarrow$ f, we much be 100% certain of the fact. Rules for $\rightarrow$ relations. $\rightarrow$ is the smallest relation such that:

- if e occured before f in the same process, then e $\rightarrow$ f
- if e is send of a message and f is the receive of that message, then e $\rightarrow$ f
- if $\exists$ g: e $\rightarrow$ g $\wedge$ g $\rightarrow$ f, then e $\rightarrow$ f

**Example:**




From the example, we can infer the following:

1. e1 $\rightarrow$ e2, e2 $\rightarrow$ e3, hence e1 $\rightarrow$ e3
2. f1 $\rightarrow$ f2, f2 $\rightarrow$ f3, hence f1 $\rightarrow$ f3
3. e2 $\rightarrow$ f3 (message sent at e2 received at f3) hence e1 $\rightarrow$ f3

**Concurrent Events:** e || f $\implies$ (e $\not\rightarrow$ f) $\wedge$ (f $\not\rightarrow$ e)

$\rightarrow$is transitive.
$\rightarrow$is irreflexive; no event can happen before itself just like < "less than" relationship.
$\rightarrow$defines relationships in the irreflexive partially ordered set.

Examples of **irreflexive asymmetric**

- (E, $\rightarrow$)
- (N, <)

where:
E is the set of all relationships defined by $\rightarrow$relationship
N is the set of all natural numbers defined by < relationship

Examples of **reflexive antisymmetric**

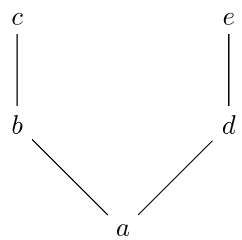
- (E, $\underline{\rightarrow}$)
- (N, $\leq$)

where:
E is the set of all relationships defined by $\underline{\rightarrow}$relationship
N is the set of all natural numbers defined by $\leq$ relationship

(e $\underline{\rightarrow}$ f) $\wedge$ (f $\underline{\rightarrow}$ e) $\implies$ e = f

## Posets

Hasse Diagram transitively reduced diagram




a < b, a < c
a < d, a < e
b < c, d < e

**Chain:** Y is a chain in X if
∀ a,b ∈ Y: (a ≤ b) ∨ (b ≤ a)
**Example:** Longest chains are (a,b,c) and (a,d,e). [Length is 3]

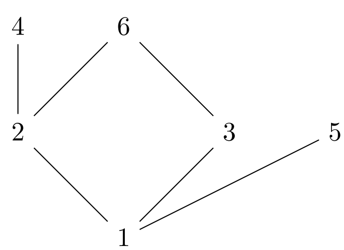
**Anti-Chain:** Y is an anti-chain in X if
∀ a,b ∈ Y: (a || b)
**Example:** Longest anti-chains are (b,d), (c,e), (c,d), (b,d). [Width is 2]

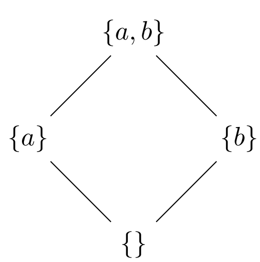
**Note:**

1. Height of poset is the longest chain
2. Width of poset is longest anti-chain

**Some More Examples**

Relation (N, divides). a ≤ b if a divides b, i.e b % a = 0



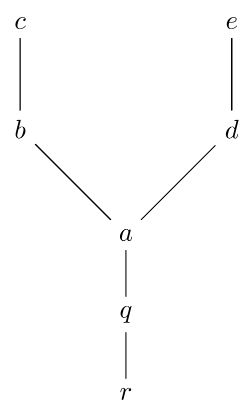

Set Y = a, b Subsets of Y:

## Infimum and Supremum

**Infimum**
Given $(X, \leq)$ & $Y \subseteq X$

$m \in X$ is the meet/infimum/"greatest lower bound" of Y if

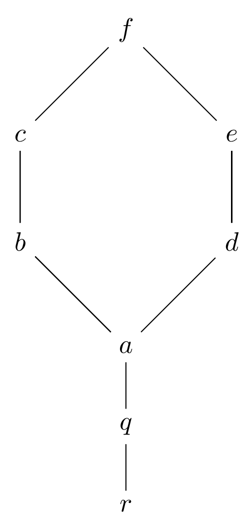
1. $\forall\ y \in Y$: $m \leq y$ {m is a lower bound}
2. $\forall\ m'$ : $[\forall\ y \in Y$: $m' \leq y]\implies m' \leq m$



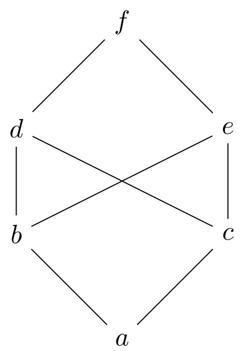

**inf** $(b,e) = a = b \sqcap e$
**inf** is represented by the symbol $(\sqcap)$

**Supremum**
Supremum is the least upper bound and is represented by the symbol $(\sqcup)$. For the example above, the sup(b,e) or $b \sqcup e$ does not exist.

A poset $(X, \leq)$ is a lattice if for all finite $Y \subseteq X$, sup(Y) and inf(Y) exist.




The example above is a lattice as for all subsets, **sup** and **inf** exist.
$b \sqcup e = f$
$b \sqcap e = a$



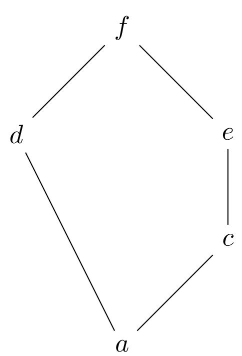

The example above is **NOT** a lattice.
b $\sqcup$ c = does not exist
b $\sqcap$ c = a

For (N, divides) poset, GCD = inf and LCM = sup.

**Distributive Property**:

1. a $\sqcap$ ( b $\sqcup$ c) = (a $\sqcap$ b) $\sqcup$ (a $\sqcap$ c)
2. a $\sqcup$ ( b $\sqcap$ c) = (a $\sqcup$ b) $\sqcap$ (a $\sqcup$ c)

**Pentagon Lattice**




The lattice above is not distributive.

**Diamond Lattice**