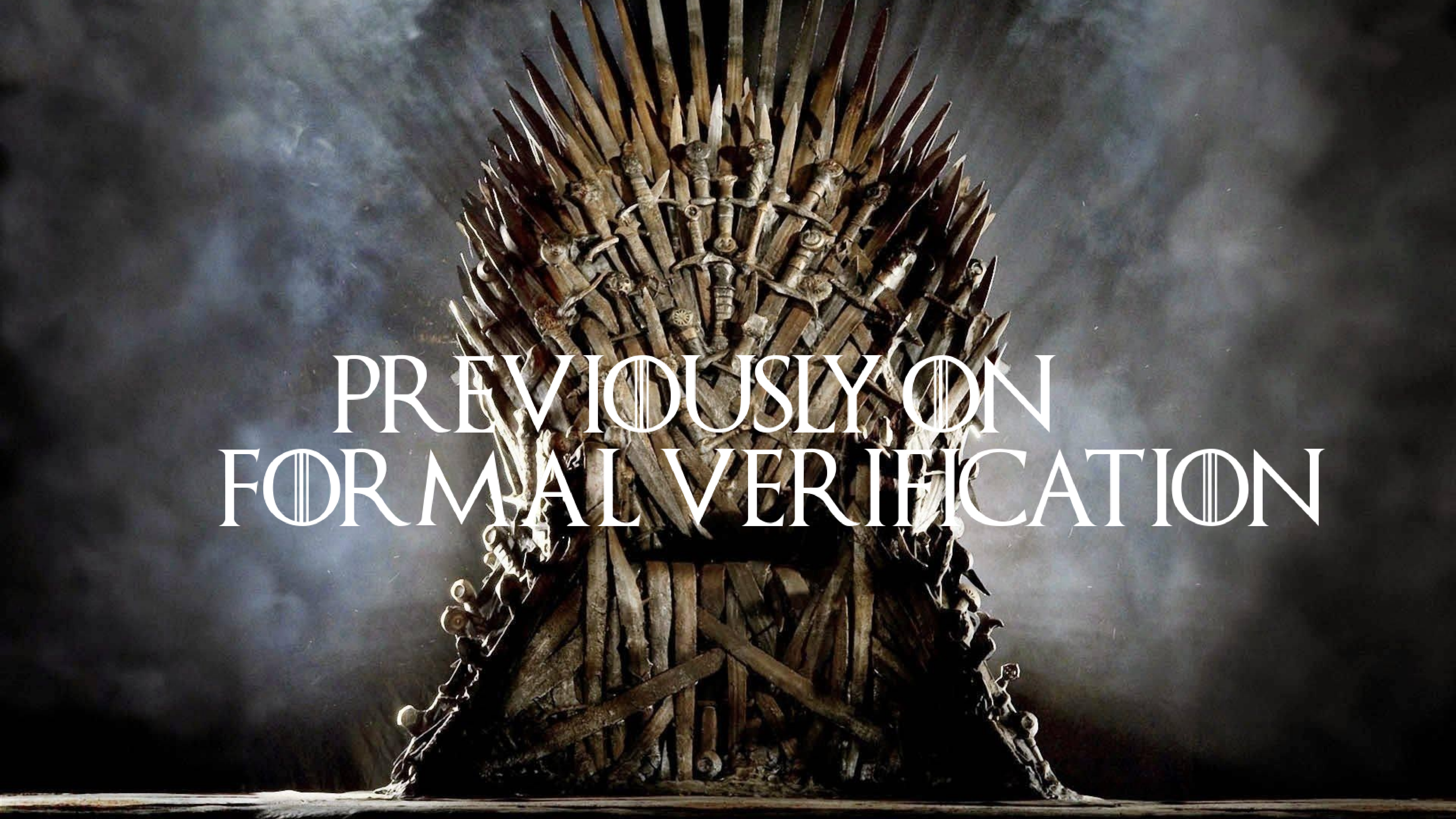
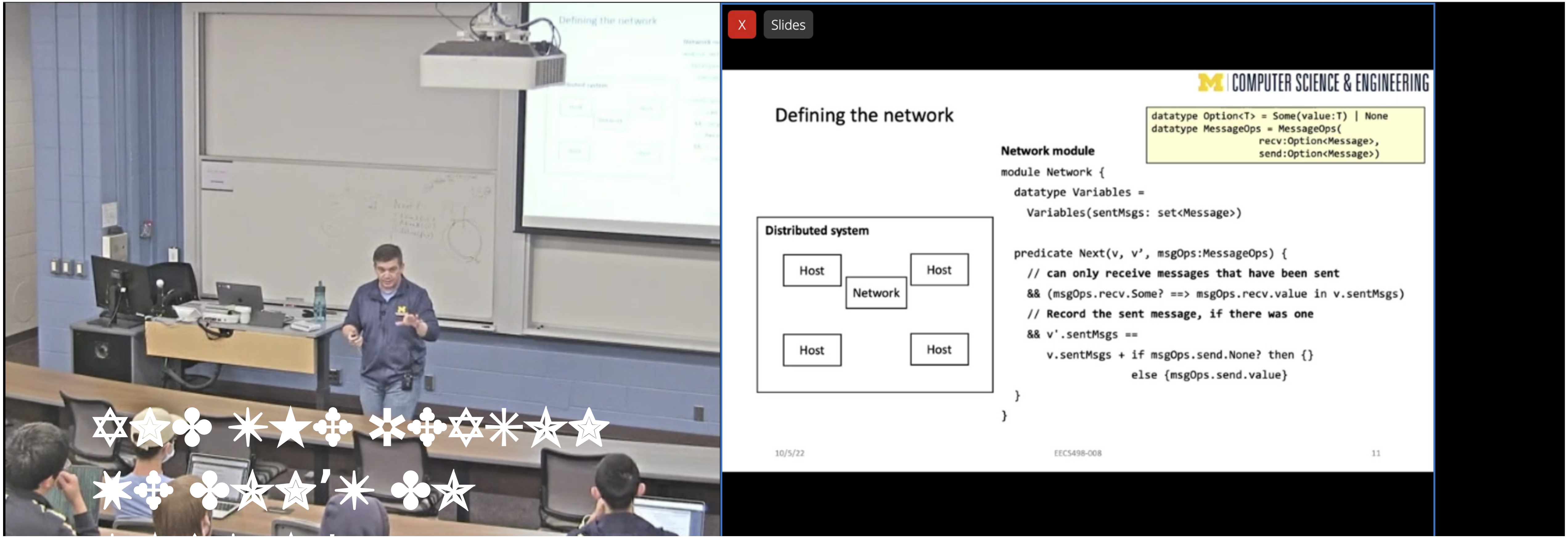
EECS498-008 Formal Verification of Systems Software

Material and slides created by

Jon Howell and Manos Kapritsos


PREVIOUSLY ON
FORMAL VERIFICATION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Slides
COMPUTER SCIENCE & ENGINEERING
Defining the network
datatype Option<T> = Some(value:T) | None
datatype MessageOps = MessageOps(
recv:Option<Message>,
send:Option<Message>)
Network module
module Network {
datatype Variables =
Variables(sentMsgs: set<Message>)
predicate Next(v, v', msgOps:MessageOps) {
// can only receive messages that have been sent
&& (msgOps.recv.Some? ==> msgOps.recv.value in v.sentMsgs)
// Record the sent message, if there was one
&& v'.sentMsgs ==
v.sentMsgs + if msgOps.send.None? then {}
else {msgOps.send.value}
}
}
Distributed system
Host
Network
Host
Host
Host
10/5/22
EECS498-008
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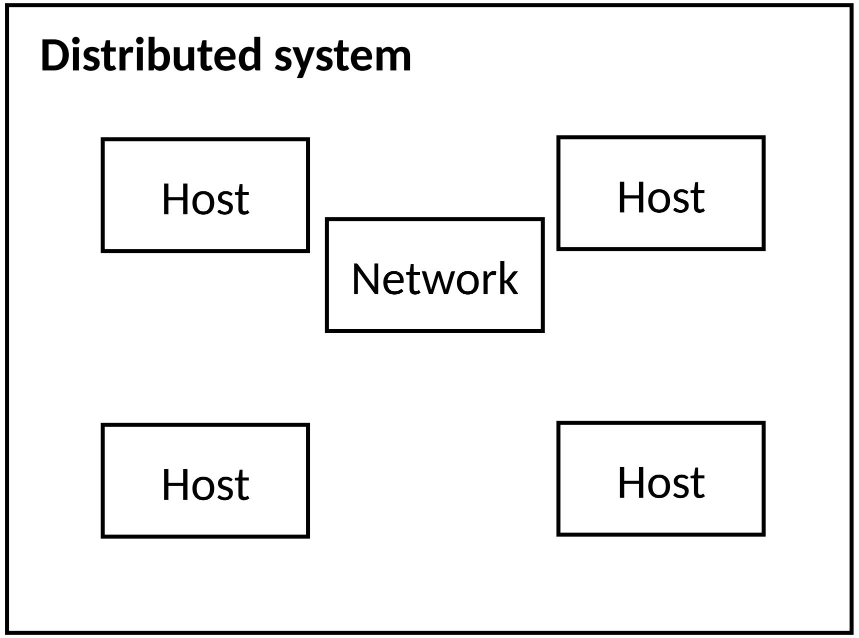
Defining the network

```
datatype Option<T> = Some(value:T) | None
datatype MessageOps = MessageOps(
                  recv:Option<Message>,
                  send:Option<Message>)
```

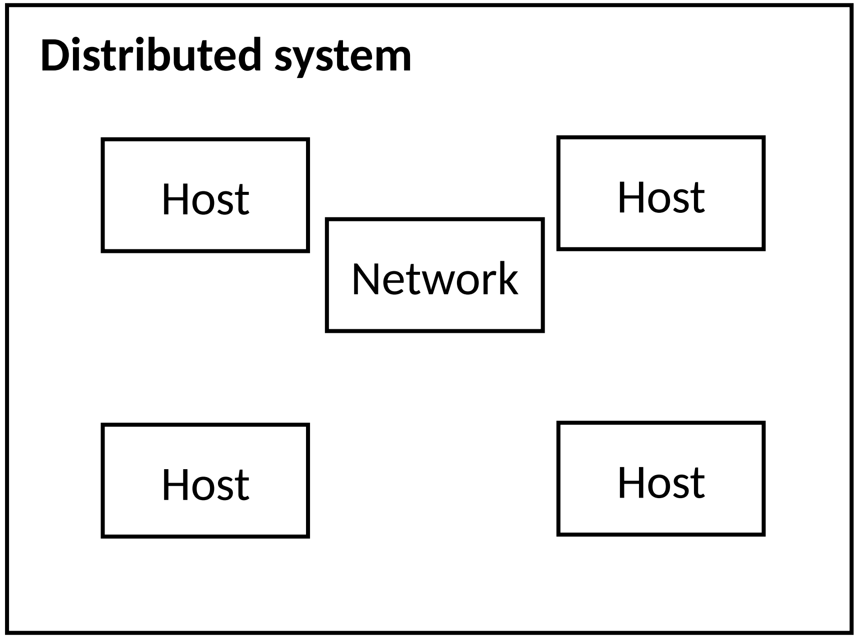


Network module

```
module Network {
  datatype Variables =
    Variables(sentMsgs: set<Message>)

  predicate Next(v, v’, msgOps:MessageOps) {
    // can only receive messages that have been sent
    && (msgOps.recv.Some? ==> msgOps.recv.value in
v.sentMsgs)
    // Record the sent message, if there was one
    && v'.sentMsgs ==
      v.sentMsgs + if msgOps.send.None? then {}
                   else {msgOps.send.value}
  }
}
```

A distributed system is composed of multiple hosts **and a network**



Distributed system: attempt #2

```
module DistributedSystem {
  datatype Variables =
    Variables(hosts:seq<Host.Variables>,
              network: Network.Variables)

  predicate HostAction(v, v’, hostid, msgOps) {
    && Host.Next(v.hosts[hostid],v'.hosts[hostid],msgOps))
    && forall otherHost:nat | otherHost != hostid ::
        v’.hosts[otherHost] == v.hosts[otherHost]
  }

  predicate Next(v, v’, hostid, msgOps: MessageOps) {
    && HostAction(v, v’, hostid, msgOps)
    && Network.Next(v, v’, msgOps)
  }
}
```

Binding variable

Administrivia

- Midterm exam **this Wednesday**, 10/12
  - 6-8pm, EECS1303
  - No lecture that day
- Closed books
  - Allowed one double-sided “cheat-sheet”, 10pt minimum
- Covers everything up to Chapter 4 (i.e. excluding distributed systems)

- Problem set 3 (Chapter 5) will be released later today
- Start looking for partners for Project 1 (released after PS3)

Atomic Commit (Problem Set 3)

-Do you take each other?

  -I do.

  -I do.

-I now pronounce you atomically committed.

Atomic Commit: the objective

Preserve data consistency for distributed transactions

Example: book a hotel and flight on Expedia

Atomic Commit: the setup

- One coordinator
- A set of participants
  - Allowed to be empty in our model
- Every participant has an “input” value, called vote/preference

$$vote_i \in \{Yes, No\}$$

- Every participant/coordinator has an “output” value, called decision

$$decision_i \in \{Commit, Abort\}$$

- We are ignoring the possibility of failures

Atomic Commit: the spec (simplified to ignore failures)

- AC-1: All processes that reach a decision reach the same one
- AC-3: The Commit decision can only be reached if all processes vote Yes
- AC-4: If ~~there are no failures and~~ all processes vote Yes, then the decision must be Commit

AC-2 and AC-5 ignored

Two Phase Commit (2PC)

Coordinator c

1. sends VOTE-REQ message to all participants

3. Wait for all votes to come in
   If all votes are Yes then
   $decision_c$:= Commit
   Send Commit message to all
   else
   $decision_c$:= Abort
   Send Abort message to all who voted Yes

Participant p_i

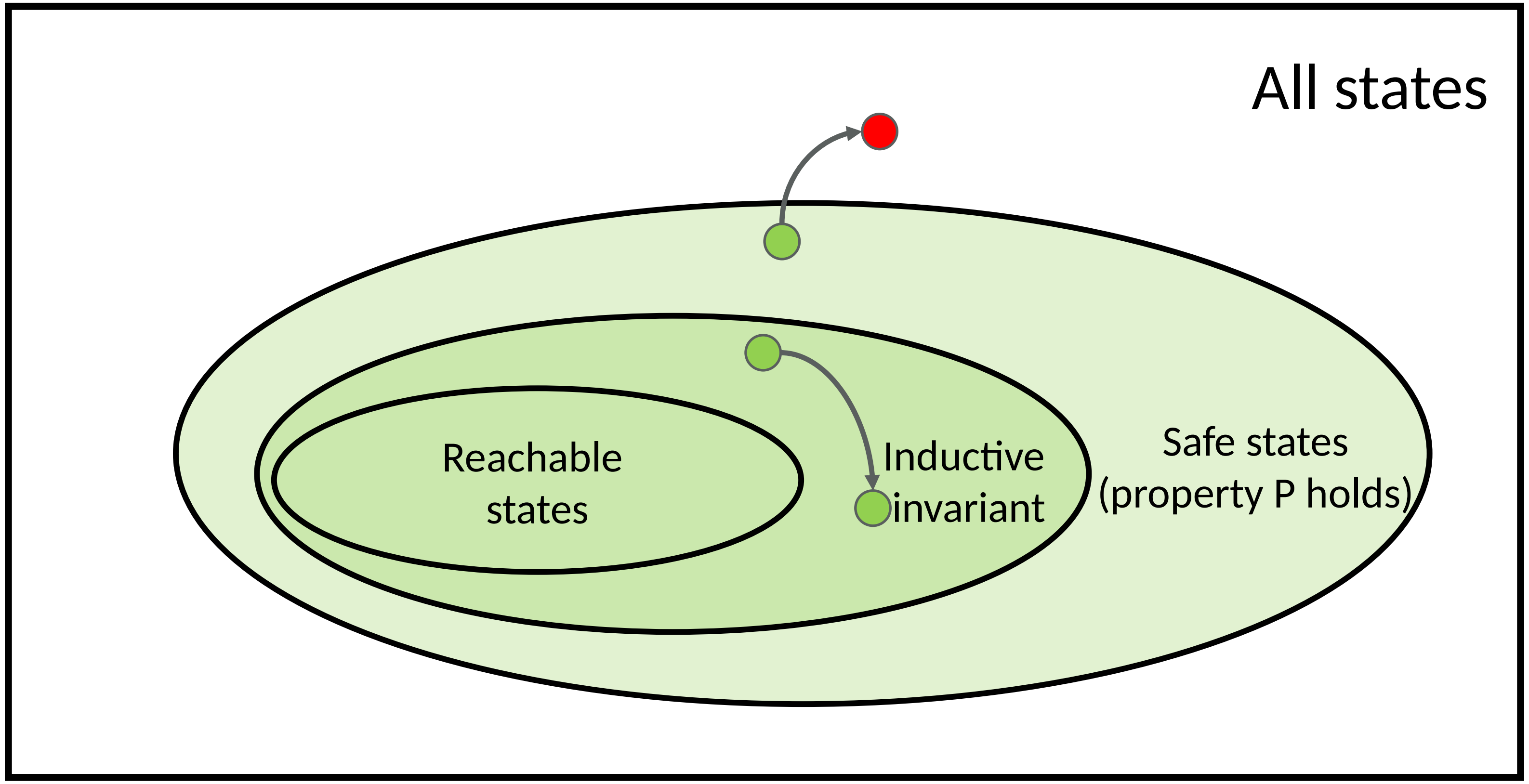
2. sends $vote_i$ to coordinator
   if $vote_i$ == No
   then $decision_i$:= Abort

4. If received Commit then
   $decision_i$:= Commit
   else
   $decision_i$:= Abort

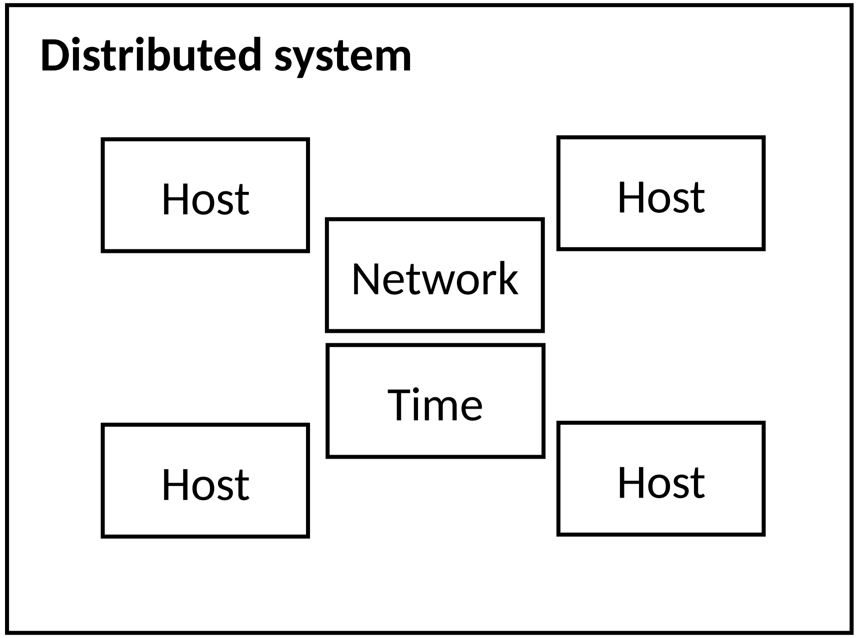
Recap of Chapters 1-4

- Chapter 1: Dafny mechanics
  - Primitive types, quantifiers, assertions, recursion, loop invariants, datatypes
- Chapter 2: Specification
  - Formally define how a system should behave
- Chapter 3: State machines
  - Express the behavior of a system using Init() and Next() predicates, JNF
- Chapter 4: Inductive invariants
  - A strengthening of the safety property to become inductive

Invariants vs Inductive invariants



A distributed system is composed of multiple hosts, **a network and clocks**

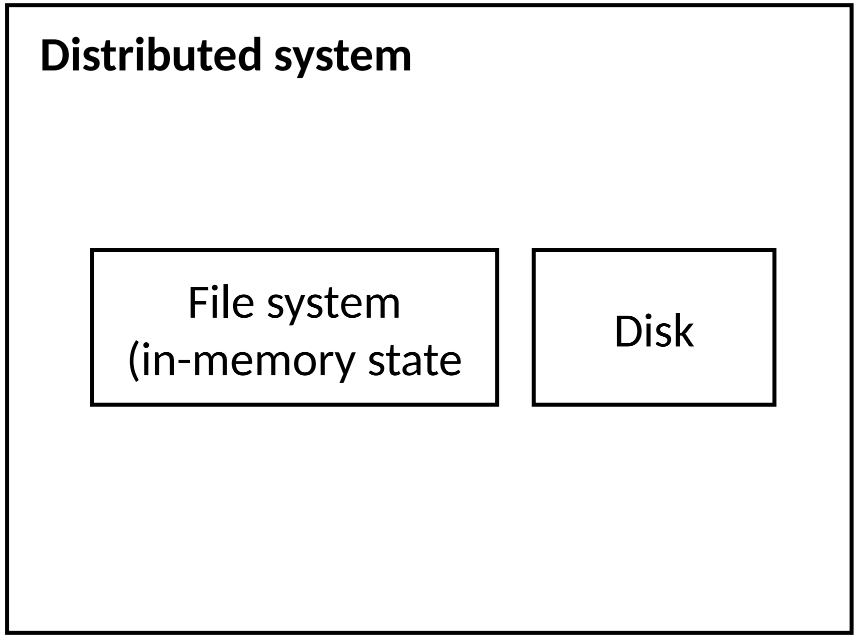


Distributed system: attempt #3

```
module DistributedSystem {
  datatype Variables =
    Variables(hosts:seq<Host.Variables>,
              network: Network.Variables,
              time: Time.Variables)

  predicate Next(v, v', hostid, msgOps: MessageOps, clk:Time) {
    || (&& HostAction(v, v', hostid, msgOps)
        && Network.Next(v, v', msgOps)
        && Time.Read(v.time, clk))
    || (&& Time.Advance(v.time, v'.time)
        && v'.hosts == v.hosts
        && v'.network == v.network)
  }
}
```

A “distributed” system

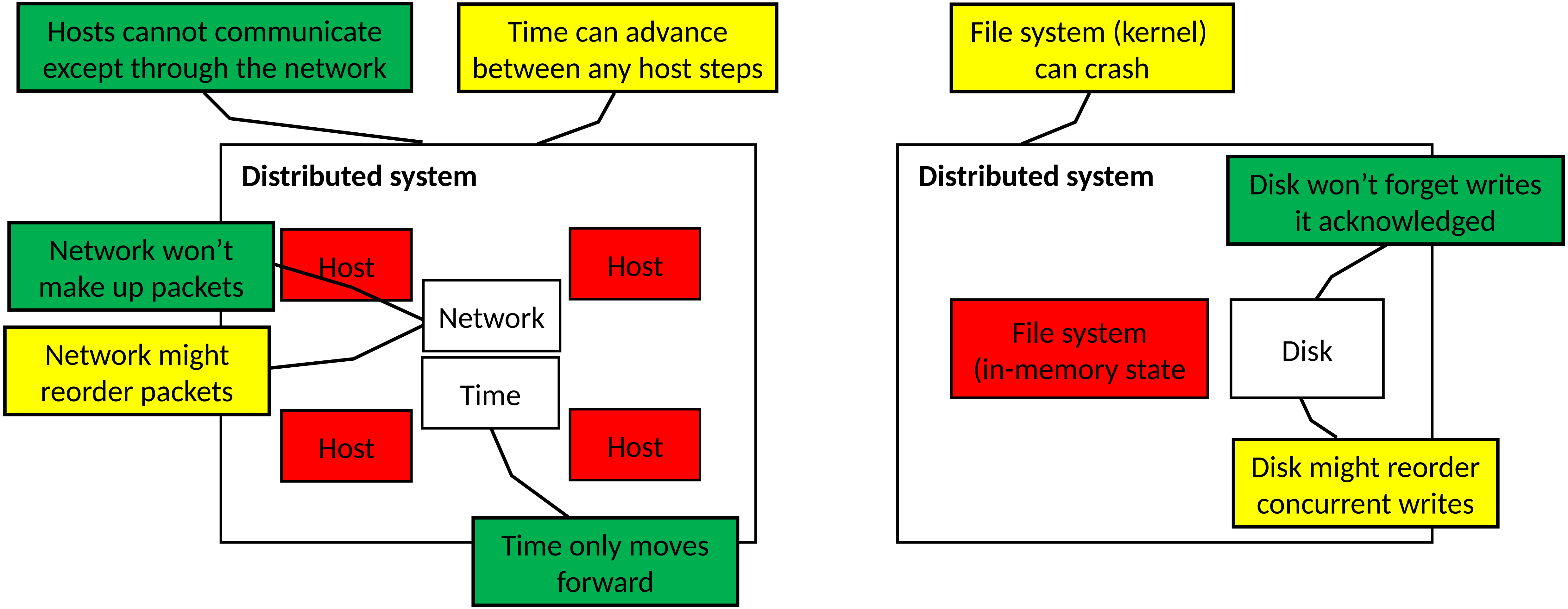



```
module DistributedSystem {
  datatype Variables =
    Variables(fs: FileSystem.Variables,
              disk: Disk.Variables)

  predicate Next(v, v’) {
    || (exists io ::
        && FileSystem.Next(v.fs, v’.fs, io)
        && Disk.Next(v.disk, v’.disk, io)
    || ( // Crash!
        && FileSystem.Init(v’.fs)
        && v’.disk == v.disk
       )
  }
}
```

Binding variable

Trusted vs proven



SPECIFICATION: the systems specification sandwich

image: pixabay