Distributed Simulation

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Outline

- Overview
- Hardware
  - Topology Examples
- Software
- DS Design Considerations
- The High Level Architecture (HLA)
- Examples of DS
- Where you can find more info on DS

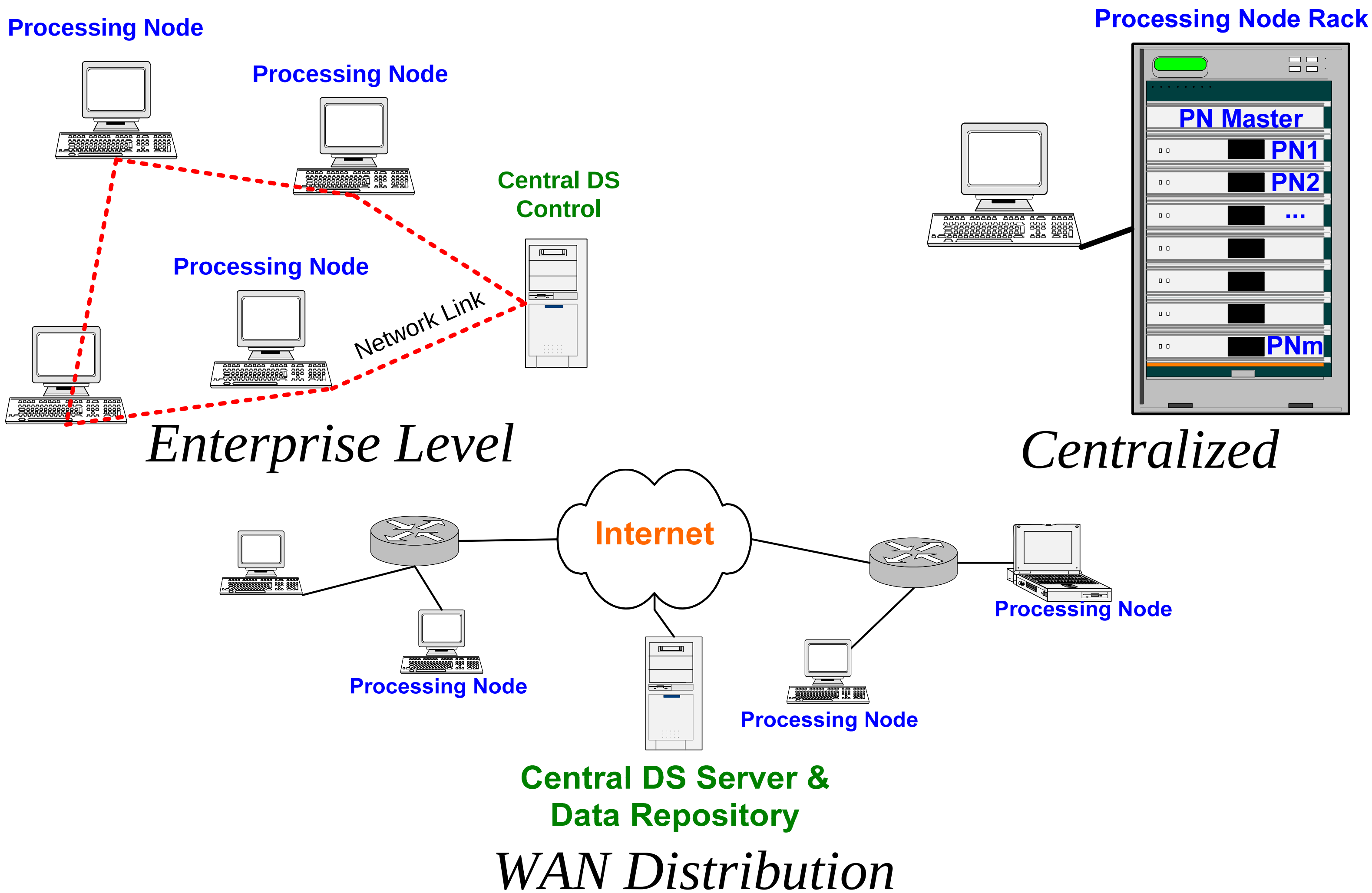
DS for Network M&S

- DS may be useful for Network M&S:
  - Networks often exhibit behavior that is non-deterministic and complex
  - Large-scale simulation often required for sufficient network modeling
    - As internet grows and becomes more wireless, current network models may not have the necessary fidelity to accurately capture network behavior
    - This is especially true for military networking systems which are highly ad-hoc and are expected to support thousands or tens of thousands of nodes at once
- Benefits:
  - DS increases the processing power of a simulation by scheduling tasks
  - Also enables abstraction by separation of simulation tasks into different simulations with standard interfaces between them
  - For Network M&S, may be well suited because of the nature of independent network process modeling, which reduces the need for strict timing requirements and significant overhead control messages
- Risks:
  - Complexity of developing a DS more than a serial simulation
  - Issues must be addressed when considering DS sim:
    - Timing (processing nodes need to be synchronized)
    - Control (a hierarchical method must be developed to maintain control of the simulation, whether via message exchange between processing nodes or some other method)

Hardware

- Generally, DS systems use multiple hosts connected in a network to perform tasks
- DS systems can be physically centralized or remotely distributed
  - X-serve Cluster in a single rack
  - SETI At Home across the entire Internet
  - Enterprise level network

DS Topology Examples



DS Software for Network Simulation

- OPNET, QualNet
  - Benefits: widely deployed, customer support, HLA options and API-compatible
  - Drawbacks: cost, complexity
- Georgia Tech PDNS
  - Benefits: open source, free
  - Drawbacks: no customer support

DS Design Considerations

- Time management and synchronization
  - Simulated events may need to be synchronized from different hardware platforms
- Simulation time
  - Tradeoffs: number of processing nodes vs. expense and overhead traffic
- Location of processing nodes
  - Localized, enterprise-wide, or internet? May affect timing significantly
- Number of processing nodes
  - Generally considered beneficial if there are more; but depending on the complexity of the simulation, may provide diminishing returns as the number increases

DS Design Considerations

- Scheduling mechanism
  - Centralized? Or Distributed? Here, a centralized case may be a server that broadcasts a particular message that all nodes receive. Alternatively, each node may have a pre-defined script loaded that instructs it to execute processes based on some event-time structure
- Network protocols and control communications between processing nodes
  - Simulation will need to be designed knowing bandwidth limits and characteristics of links between processing nodes and any master repository
- Interfaces between federated simulations (APIs)
  - Simulations of simulations will need APIs defined between federated simulations—HLA is one approach to this, but overhead messaging may be prohibitive to implement fully.
- Generally, a good simulation design will be unique to the problem it's trying to solve (isn't this what we've always heard?)

High Level Architecture (HLA)

- Grew from a DoD mandate to increase simulation capabilities in the 1990s
- Ratified in 1996 as an adopted standard for DoD
- Defines a rich architecture for DS that addresses and establishes the necessary processes
- Ratified in 2000 as IEEE Standard 1516
- Overhead intensive, but comprehensive
  - Analogous to programming: C vs. C++

OPNET Distributed Sim

- Co-Simulation API
  - Allows interface of external simulators directly with OPNET sim engine
  - Useful for abstracting communications performance to other higher-fidelity simulations (e.g. platform-specific mobility sims)
- Parallel Simulation
  - Multiple processors can be used to increase performance
  - Performance benefits vary depending on simulation scenario
- HLA Distributed Simulation module available for HLA-compliant interface

Georgia Tech PDNS

- Parallel/Distributed Network Simulator
  - PADS research group at GT developed extensions/enhancements to open-source ns simulator
- Performance/Specifications
  - Tested on as many as 136 processors simulating 600,000+ nodes
  - Processing nodes connected via TCP/IP/Ethernet
  - Performance benefits based upon many factors
    - Simulation scenario, number of processing nodes, number of simulated nodes, traffic model
    - Tests at GT PADS with 8 processing nodes showed speed gains equal to 8 (near perfect), to less than one equivalent processing node

DS Hardware: Clusters

- Apple has developed rack-mount servers that can be exploited together to form a cluster computing platform
  - Highly scalable
  - Software available to schedule multiple tasks in parallel
- This can be done with PCs as well (e.g. Dell rackmount servers)
- One such example is the VT Terascale System discussed later

Examples of DS Systems and Programs

- Virginia Tech Terascale Computing Facility
- DoD High Performance Computing Modernization Program (HPCMP)

Virginia Tech Terascale

- 1100 X-serve processing nodes…each:
  - Dual 2.3 GHz PPC 970 FX
  - 4 GB PC3200
- 3 X-serve cluster head nodes
- 2.7 TB of user storage
- Software for scheduling and distribution:
  - Torque, Moab

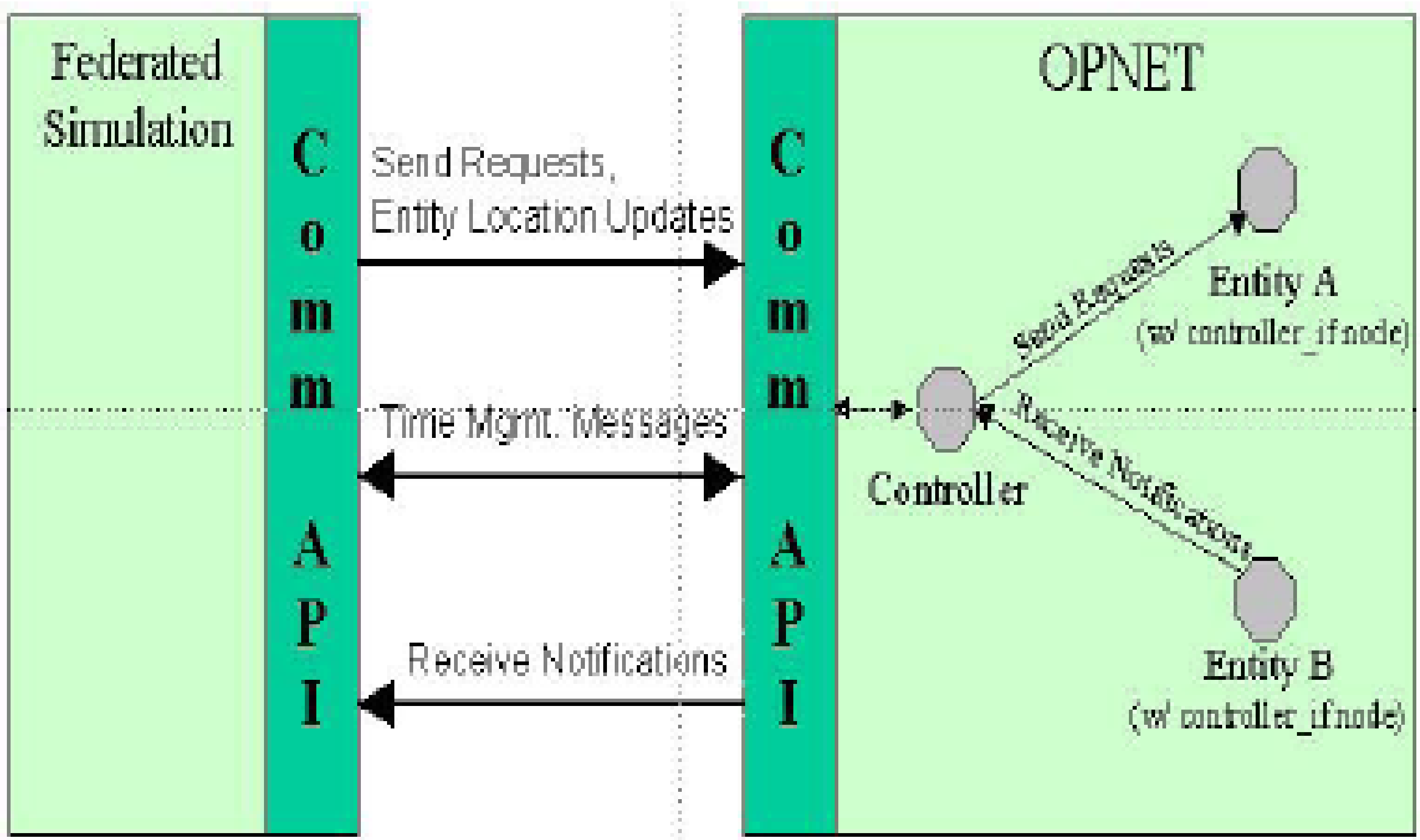
DoD HPCMP

- **DoD HPCMP is a program that makes available high-performance computing resources for modeling and simulation related to projects sponsored by DoD**
  - **Some examples: Future Combat Systems M&S, ForceNET M&S**
- **The computing resources are free for use by any DoD contractor that submits a proposal, but requests must be made in advance for scheduling computing time**

An OPNET DS Example

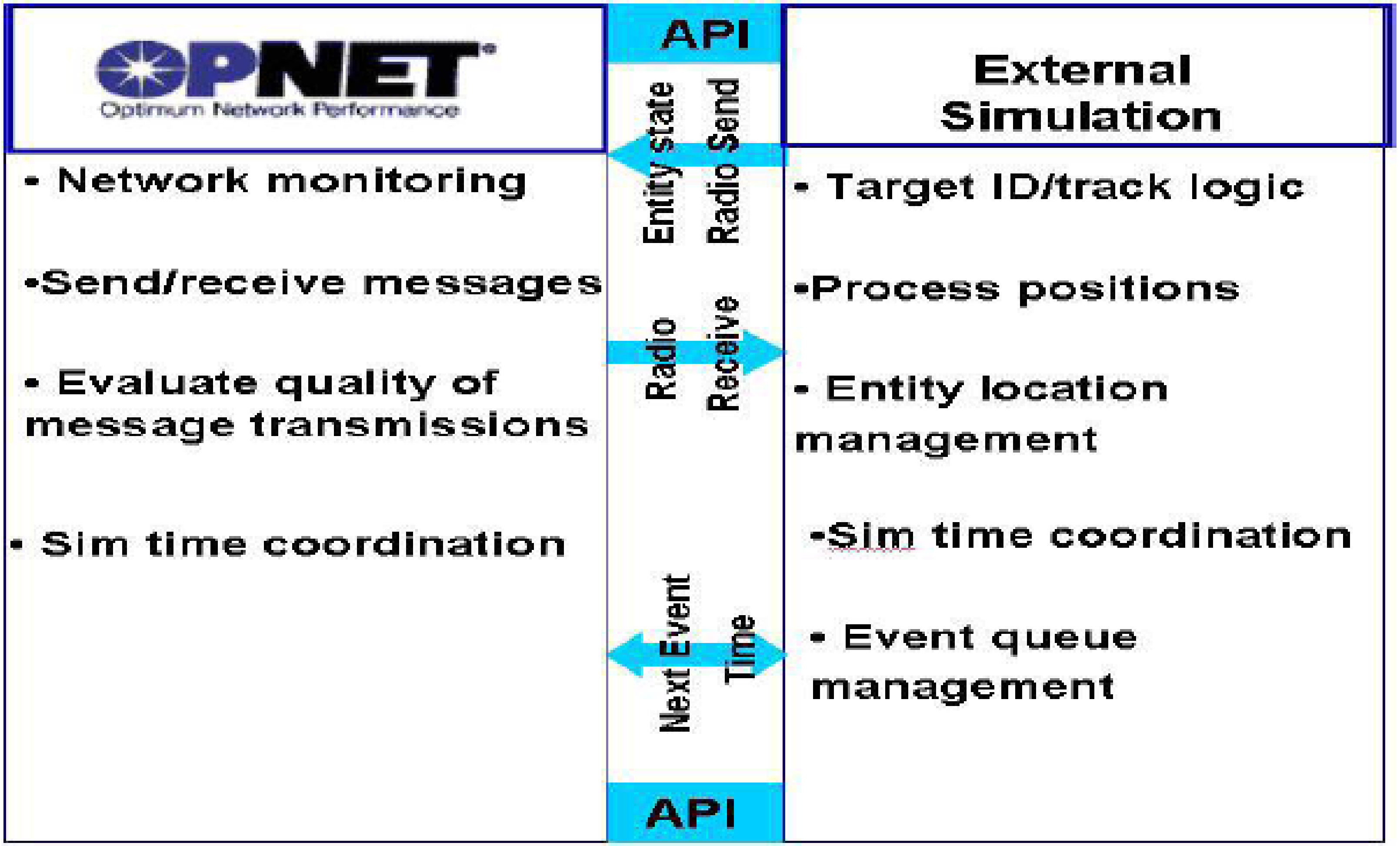
- Dooley, et al. presented an OPNET DS Network Model for Air Traffic Control
- Interfaces with OPNET via an API
- Consists of a controller and communications API
  - Controller provides time and event coordination to keep OPNET sim time and events coordinated with the distributed sim time, and spatial assignment of OPNET entities
  - Communications API provides time management to coordinate simulation time between the two separate simulations, send requests from non-OPNET sims for applications within the sim that have messages to send, receive notifications by OPNET sim that network app message has been received, entity updates to allow non-OPNET sims to set location (lat, lon, altitude) of entities.

Air Traffic Control DS Example Architecture



*taken from Dooley, et al., "Integrating Behavioral Models with Detailed OPNET Network Models in a Distributed Framework"

Air Traffic Control DS Example
Simulation Roles



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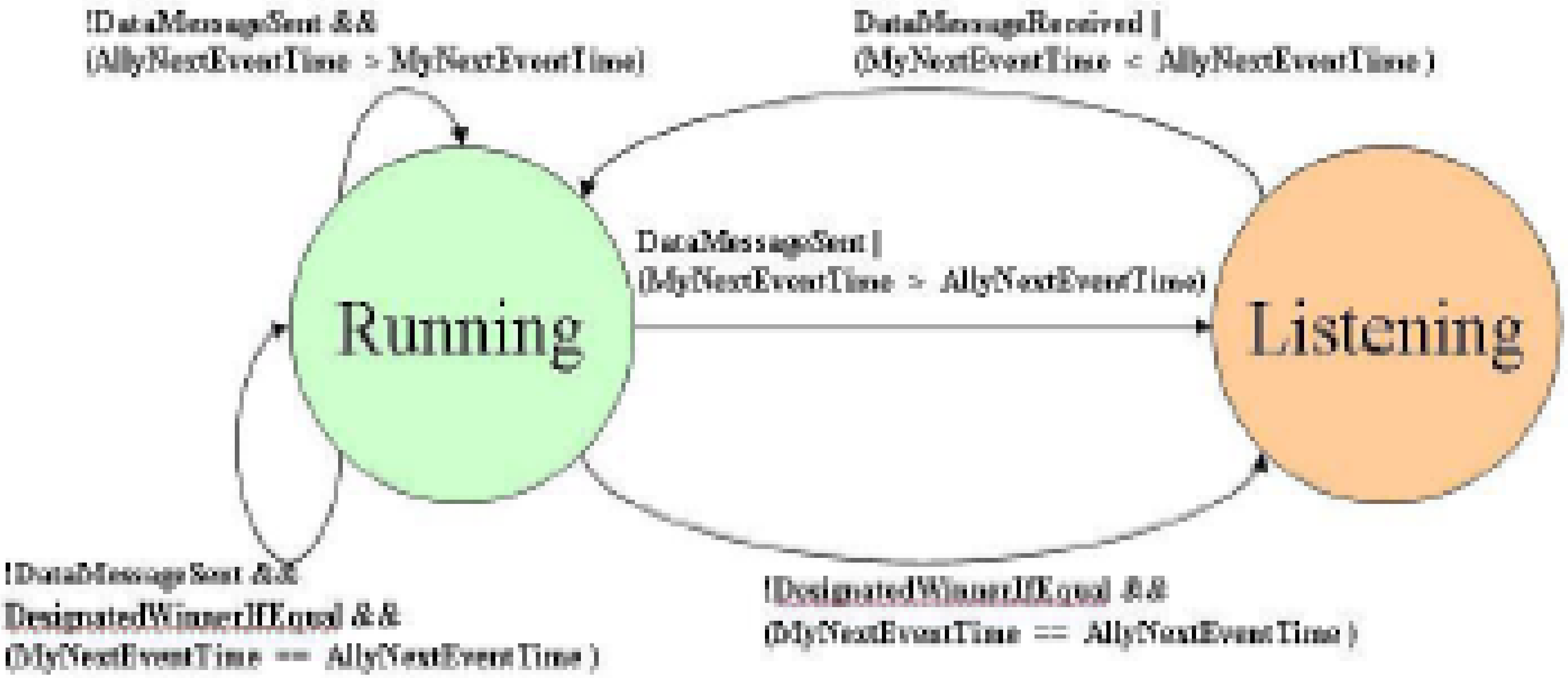
Air Traffic Control DS Example
DS State Machine



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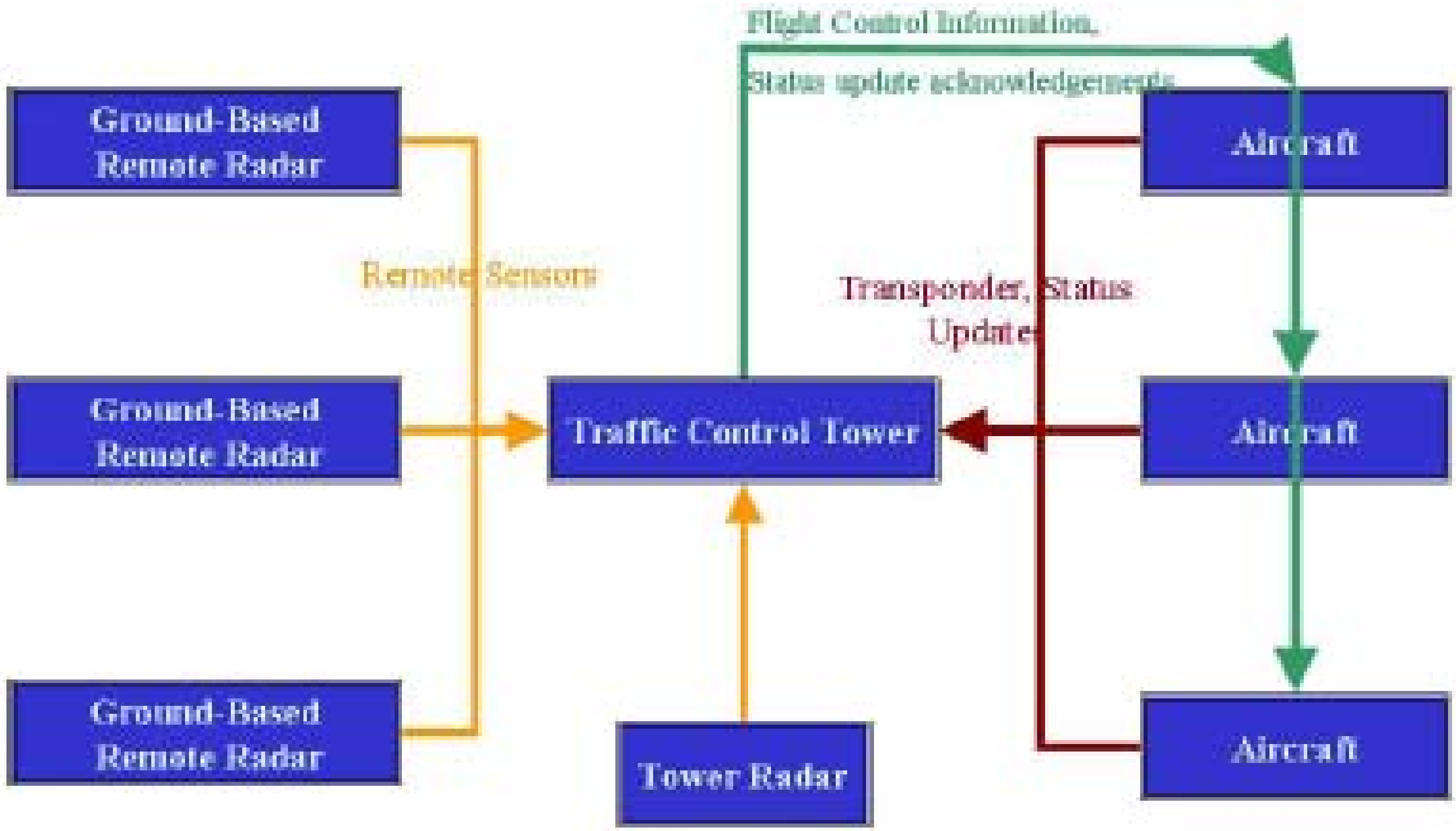
Air Traffic Control DS Example Dataflow



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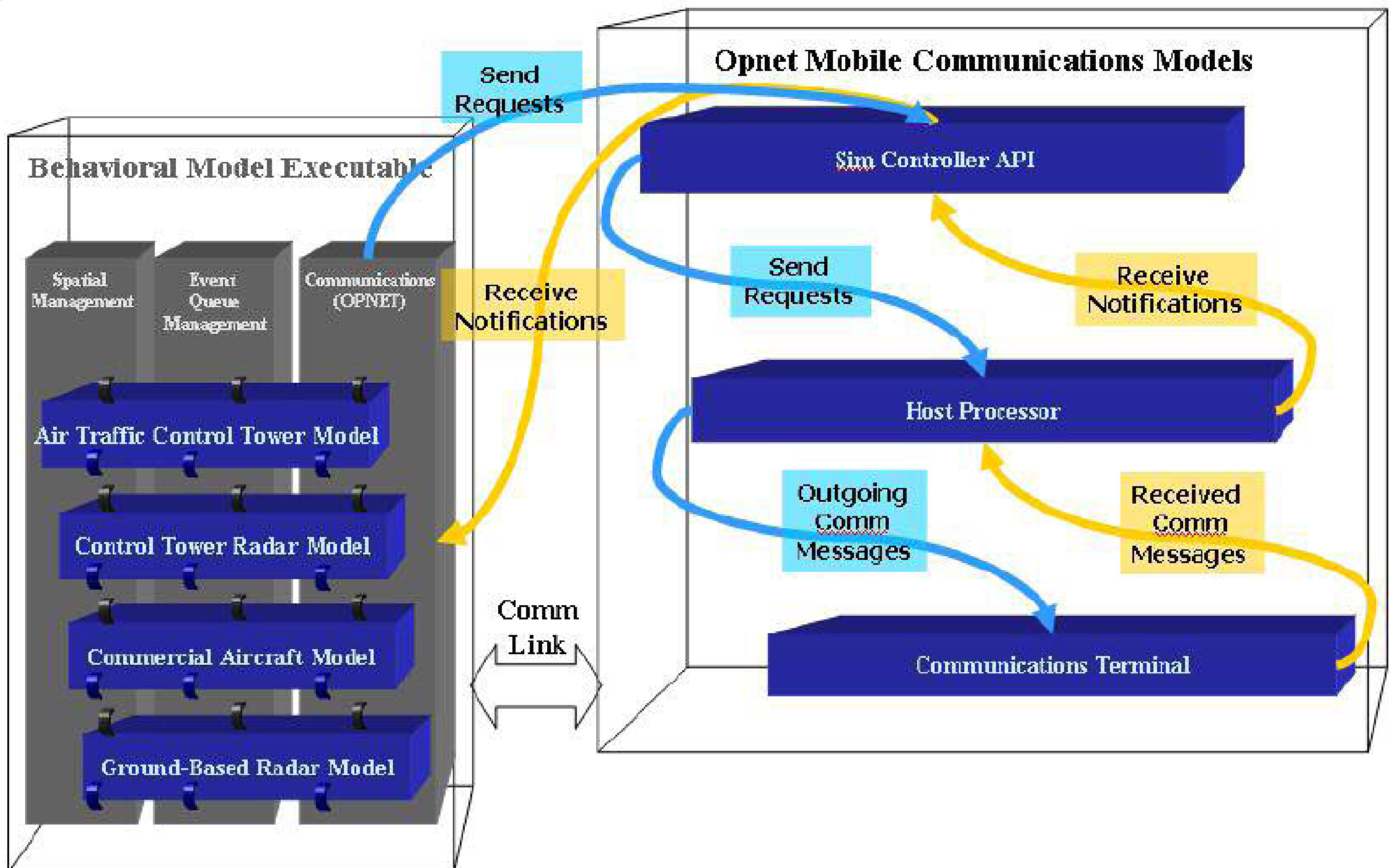
Air Traffic Control DS Example
Message Process



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Conclusions

- Advances in processing power have moved forward relentlessly
- But networked processing power provides an even greater benefit
  - Example: dual-core processor computers
  - DS for network M&S
- DS well-suited for network M&S:
  - Nature of networks similar to the simulation network topology itself

More Info on DS

- http://www.fas.org/man/dod-101/army/docs/astmp/c6/P6C3.htm
- http://dsonline.computer.org/portal/site/dsonline/index.jsp
- http://www.tcf.vt.edu/systemX.html
- http://www.hpcmo.hpc.mil/
- http://www.opnet.com
- http://www.cc.gatech.edu/computing/compass/pdns/
- http://www.apple.com/xserve/
- https://www.dmso.mil/public/transition/hla/