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Mobile Ad Hoc Communications with Strong Physical Layer Interactions

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Overview

- Introduction to Mobile Ad Hoc Networking and Strong Physical Layer Interactions
  - OSI Layers
  - Nature of STK Communications Module
  - Nature of major network simulations
  - Co-Simulation Issues
- STK-QualNet interaction
- Benchmark-STK-QualNet (BSQ) Capability
- Missile Defense Communication Example
- Conclusion

Logic of the Open Systems Interconnect (OSI) Framework in Mobile Ad Hoc Networks

- Physical Layer
  - The environment must be able to support communications
    - Channel loss (obstructions, atmospherics)
    - Interference
    - Mechanical and physical incompatibilities
- Data Link Layer
  - Establish presence in the medium. Must establish pathways within the communications medium and make physical links consistent (Mac)
- Network Layer
  - Determine topology
- Transport Layer
  - Address and transport packets, queueing, buffering, routing
- Application Layer
  - Data packaging and formatting

Mobile Ad Hoc Networking (MANET)

- Self-organizing networks of dynamically mobile elements independent of fixed infrastructure or centralized control
- General characteristics
  - Dynamic and often unpredictable network tolopogy
  - Variable capacity, often congested, bandwidth limited links
  - Energy and power constrained
  - Low physical security

Protocol and Architectural Approaches to Mitigating Routing Issues

- Link layer protocol approaches
  - Proactive: regularly scheduled route discovery
  - Reactive: route discovery in response to link loss
- Architectural approaches
  - Flat: all nodes equal
  - Hierarchical: some nodes elected or designated for special functionality
- Hybrid approaches
  - Some proactive, some reactive
  - Some flat, some hierarchical

Comparison Of Fixed And Ad Hoc Network Routing

- FIXED NETWORKS: Exploit static routing tables
  - Distance Vector: "Shortest" path
  - Link State: Avoid contention and broken links
- AD HOC NETWORK ANALOGIES
  - DISTANCE VECTOR
    - Ad Hoc On Demand Distance Vector (AODV) (Reactive/Flat)
    - Dynamic Source Routing (DSR) (Reactive/Flat)
  - LINK STATE
    - Optimized Link State Routing (OLSR) (Proactive/Flat)

Bellman-Ford: In any graph There exists a spanning tree, a set of arcs that visits every node exactly once.

Ad Hoc Networking Requires a Much Richer Spectrum of Routing Techniques Than Fixed or Static Networks Do

Possible Protocol Choices

Proactive:
TBRF and WRP

Reactive:
AODV and DSR

Hierarchical:
ZRP

Geographical:
DREAM

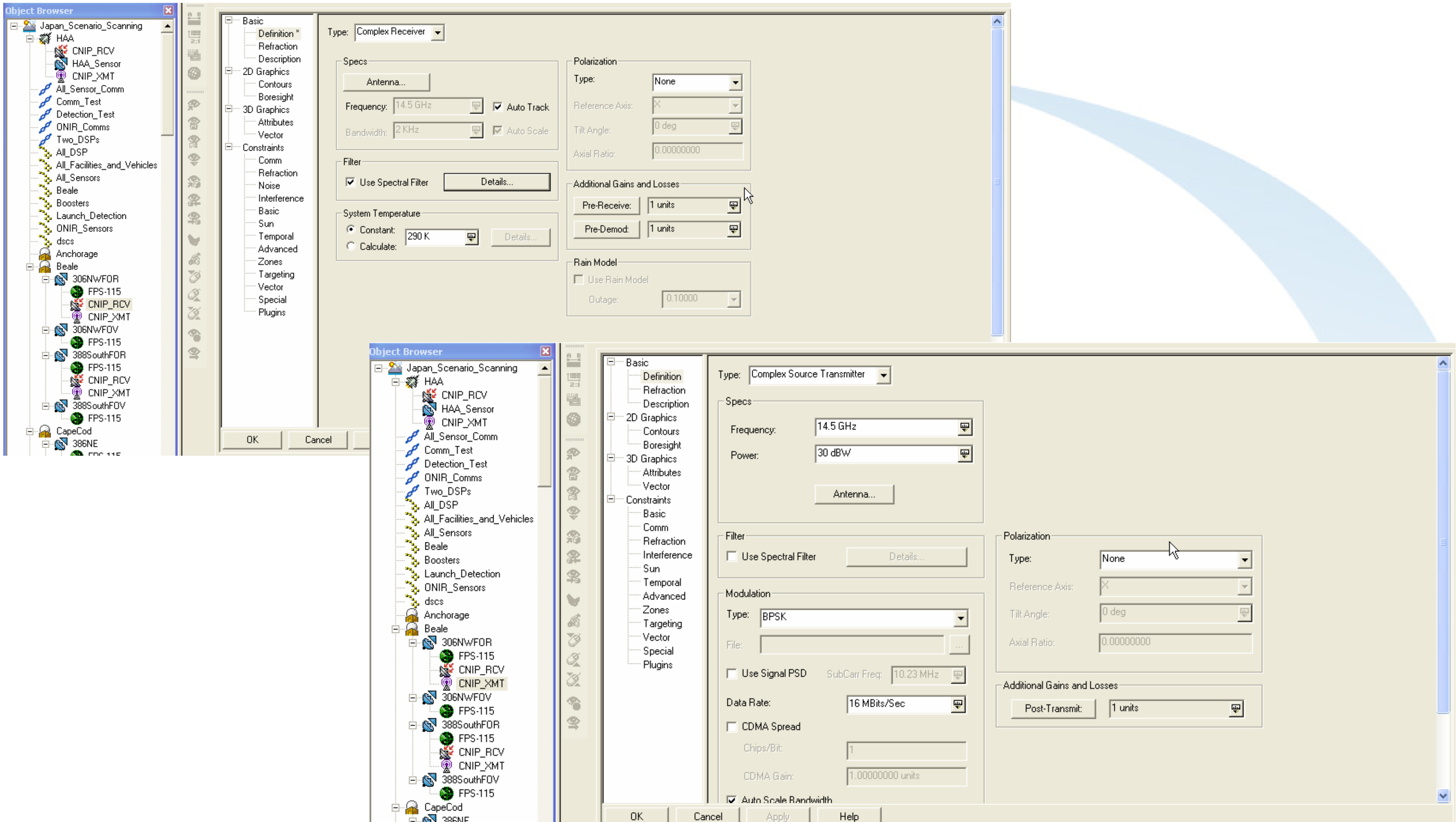
Multicast:
MAODV and ODMRP

Parameters	*TBRPF*	*WRP*	*AODV*	*DSR*	*ZRP*	*DREAM*	*ODMRP*	*MAODV*
Routing approach	Flat	Flat*	Flat	Flat	Hierarchical	Flat/ Geographical	Flat-Mesh based	Flat-Tree based
Routing scheme	Proactive	Proactive	Reactive	Reactive	Hybrid**	Proactive	Reactive	Reactive
Delivery structure	The next hop routing	Source routing	The next hop routing	Source routing	The next hop routing and source routing	Location-based flooding or location-based set next hop routing	Group-based forwarding	Core-based tree
Loop free	Yes	Yes, but not instantaneous	Yes	Yes	Yes	Yes	Yes	Yes
Multiple paths	No	No	No	Yes	Yes	Yes	Yes	No
Routing metric	Shortest path	Shortest path	Freshest and shortest patch	Shortest path	Local shortest path	Shortest path	Shortest path	Shortest path
Frequency of updates	Periodically and as needed (link change)	Periodically and as needed	As needed (data traffic)	As needed (data traffic)	Periodically and as needed	Periodically	Periodically and as needed	As needed
Multicast capabilities	No	No	Yes	No	Yes	No	Yes	Yes

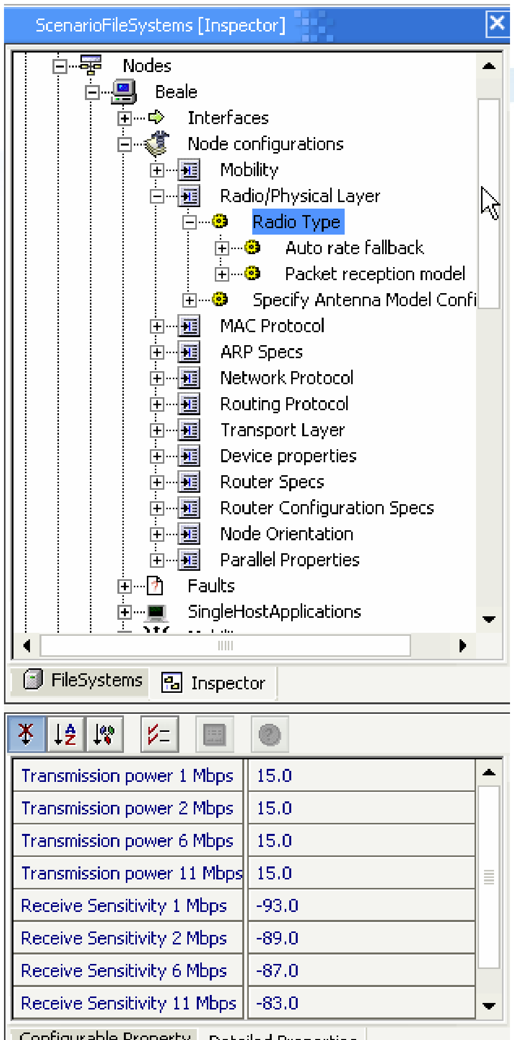
Table 1: Characteristics of chosen protocols

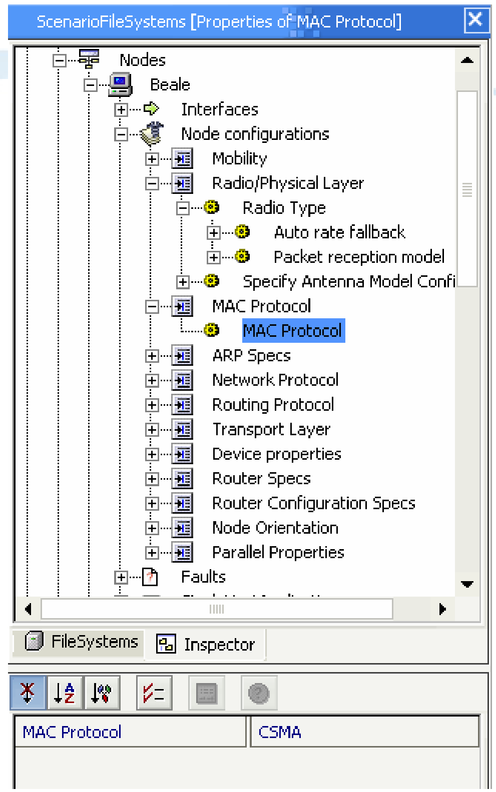
* While WRP uses flat addressing, it can be used hierarchically.
** Hybrid = Inside zone → proactive, Outside zone → reactive.

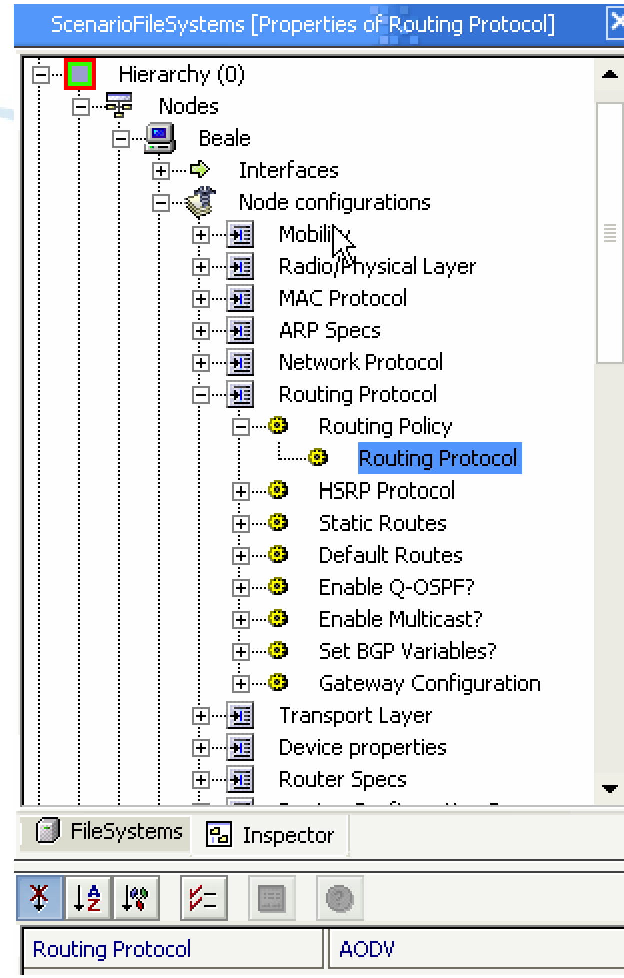
STK Transmitters and Receivers



Network Simulation Objects







Comm Link Issues

- Sources of impairment are distributed among all layers
  - Propagation Delay (Layer 1)
    - Speed of light plus medium phenomenology
  - Transmission Delay (Layer 2)
    - Serialization and Protocol Overhead
  - Processing Delay (Layer 3)
    - Switching and Queuing – Routers and Buffers
  - Rotation Delay (Layers 4-7)
    - Application specific commands
    - How a Server calls up data and presents it on a client device

Physics and Simulation Issues

- Satisfying physical layer constraints is necessary but not sufficient
  - Communication can still fail even though there is line of sight and link margin
- Communication network simulations …
  - Generally assume that the physical world is frozen while network transactions evolve
  - Are event driven
  - Often represent mobility discretely
    - Doppler accelerations may be discontinuous
  - Almost always represent satellites as geostationary retransmitters
- Physical layer simulations …
  - Have no paradigm for wired networks

Mobile Networking With Strong Physical Layer Interactions

- Physical phenomena occur on the same time scale or more rapidly than network transactions
  - Deep space with long propagation delays
    - Many protocols are intolerant of delays
  - Hypervelocity vehicles
    - Routes cease to exist before they can be used
- Very strong and rapid cross-layer interactions

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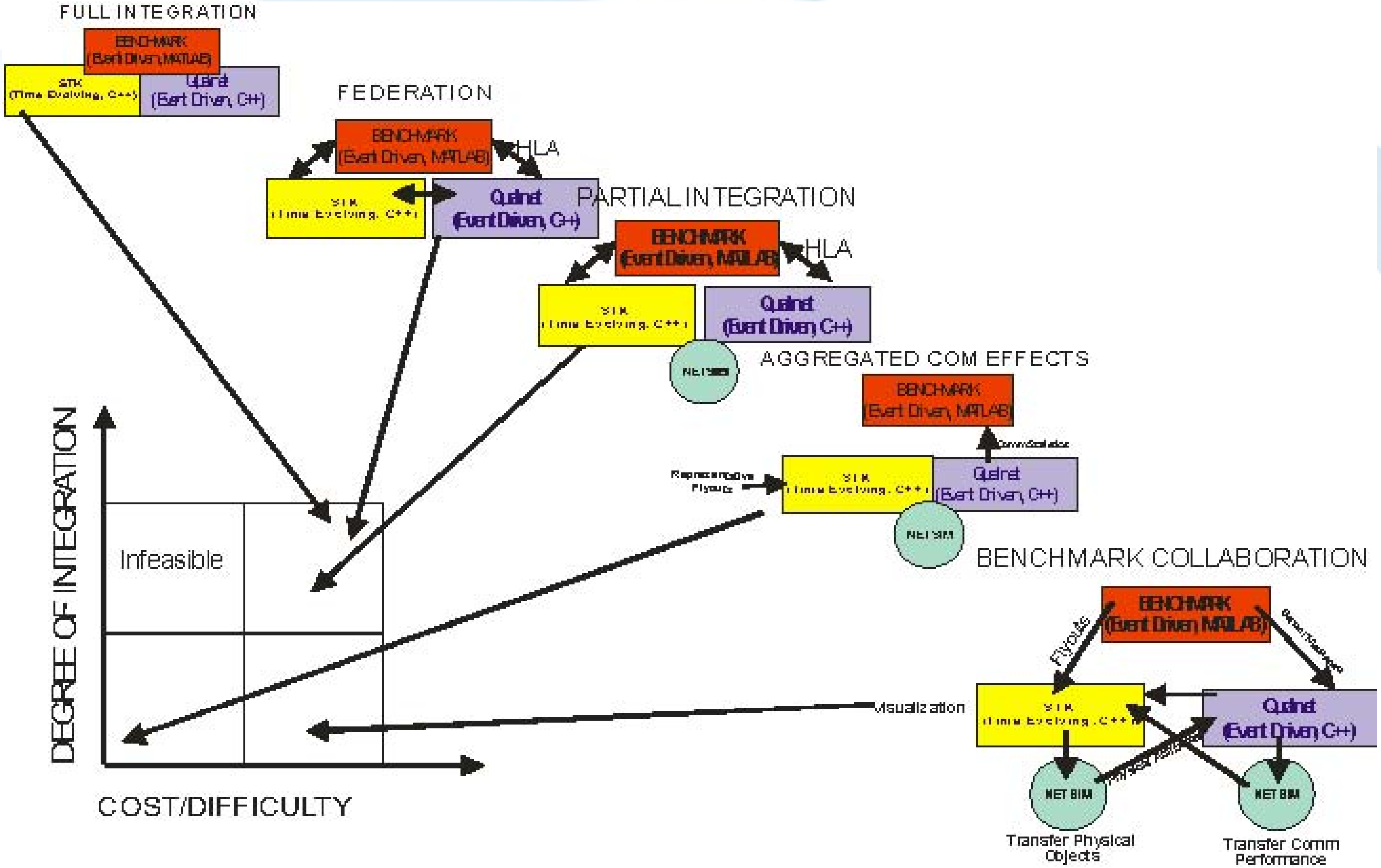
Simulation Environment Evolution



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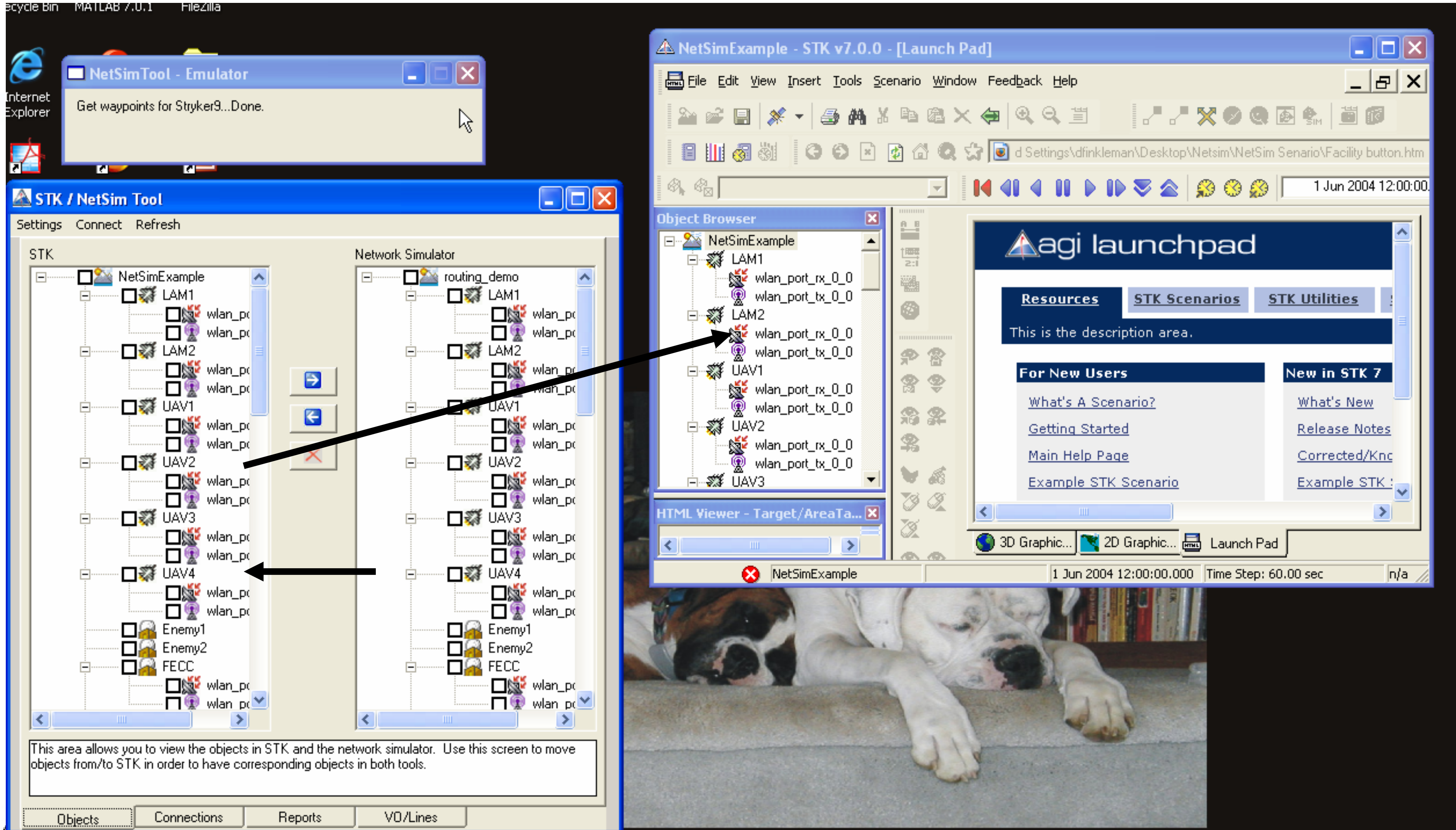
Meghan McDermott, 8/22/2006

MMcD2

NetSim Concept



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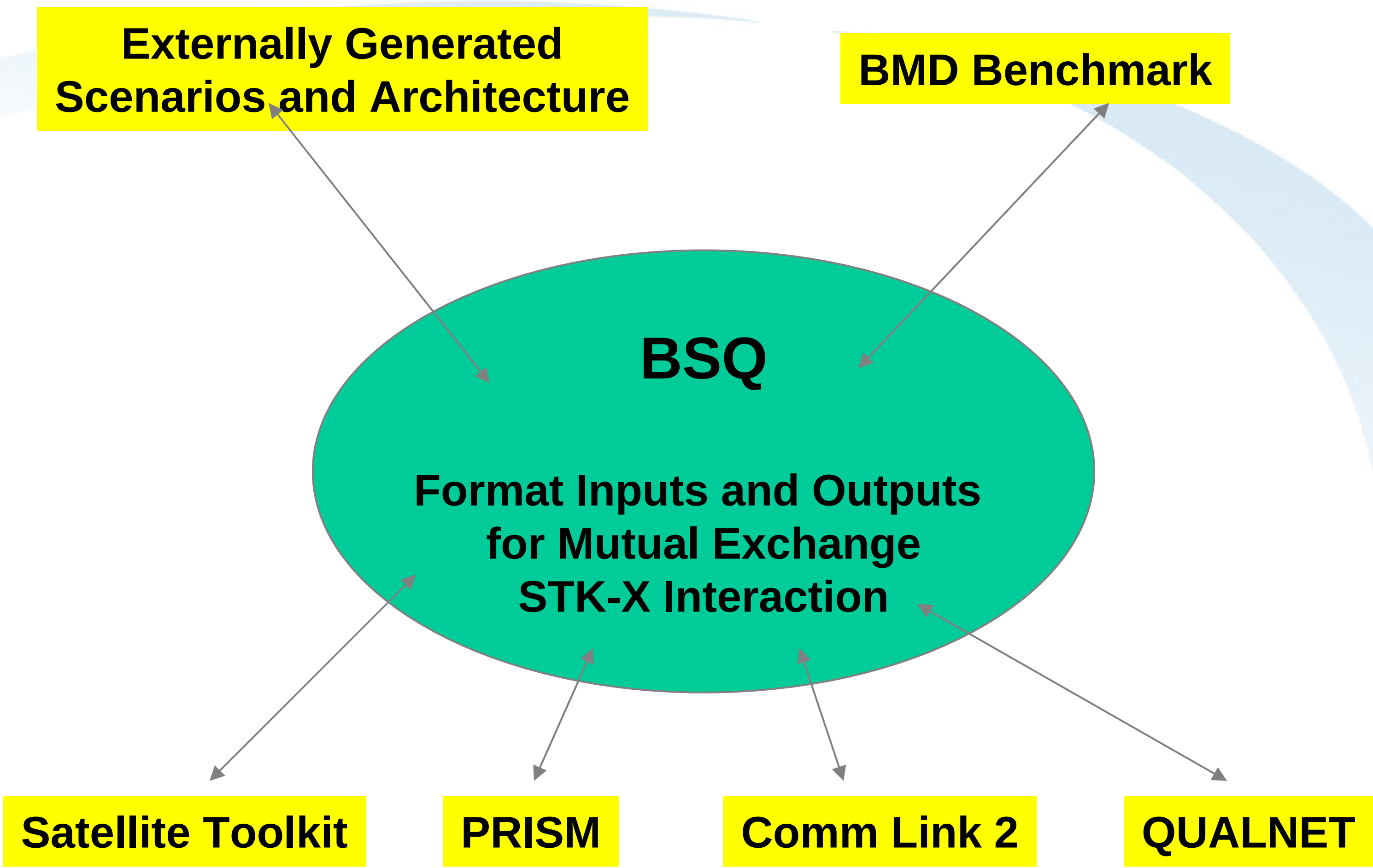
Meghan McDermott, 8/22/2006

NetSim Limitations

- One-time physical layer assessment
  - Cross layer processes difficult to represent
- Limited interchange of comm host attributes
- Mobility represented by multiple waypoints
- NetSim executes only wireless links
- Significant effort to instantiate network components and Layer 2-5 processes

Benchmark-STK-QualNet (BSQ)



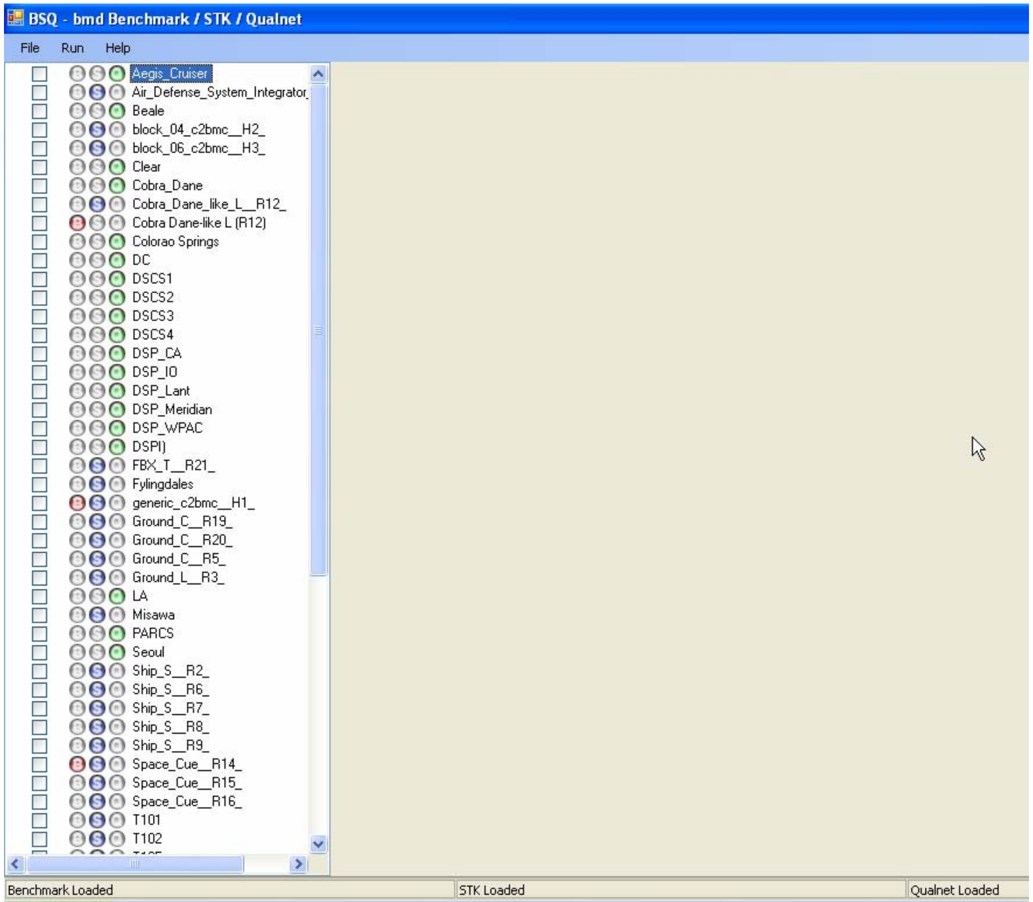
BSQ Development

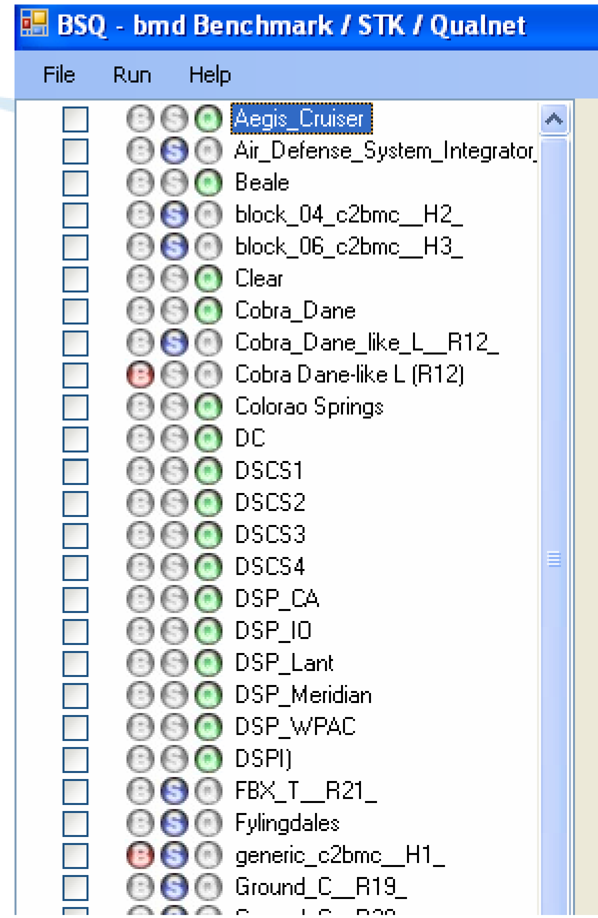
- Vehicle to extract objects and data from interacting simulations and distribute objects and data among the simulations
  - Benchmark input files into STK
  - Benchmark Message Streams from Hosts into QualNet
  - STK objects into QualNet
  - QualNet message deliveries into Benchmark
  - QualNet connectivity into STK
- Tool to generate or modify Benchmark input scenarios rapidly
- Standalone interface between any pair of simulations

BSQ Development Issues

- Different object parent-child relationships in each participating simulation
  - Benchmark spawns children of the parent missile object for every staging or deployment event
  - STK creates independent objects at the same level for each stage or deployed object
  - QualNet embeds all OSI layer characteristics within each Host object
- Different program architectures

BSQ Application





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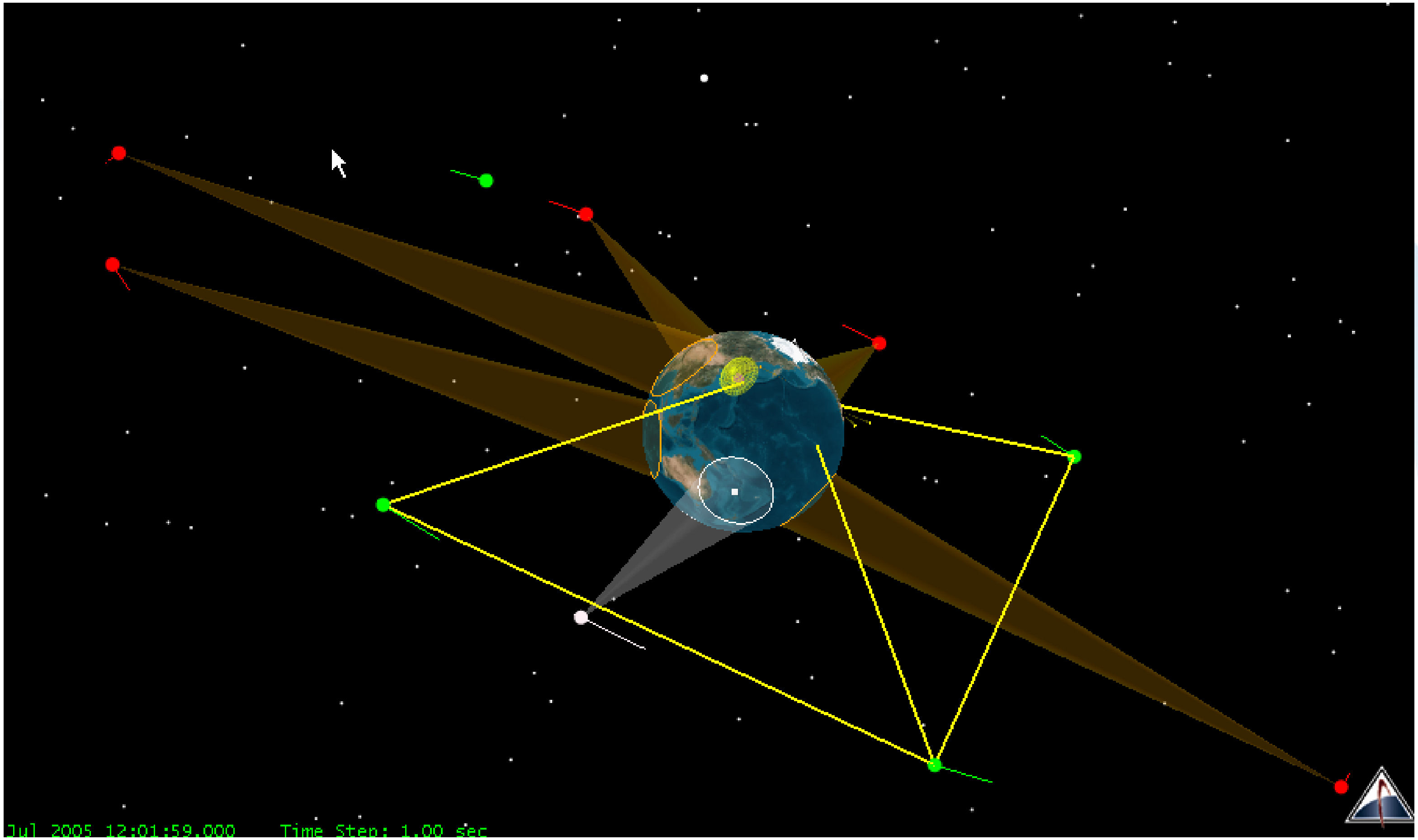
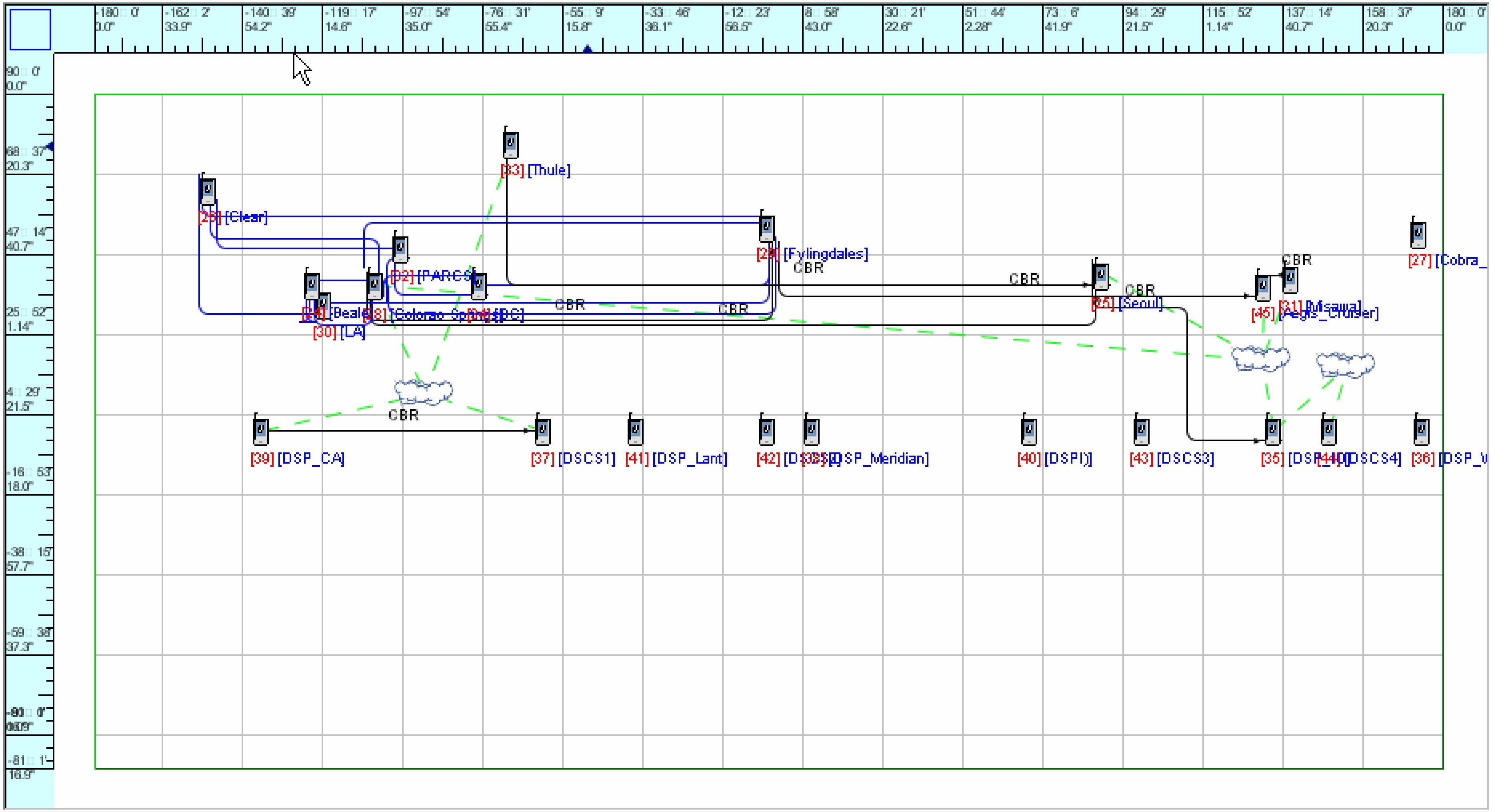
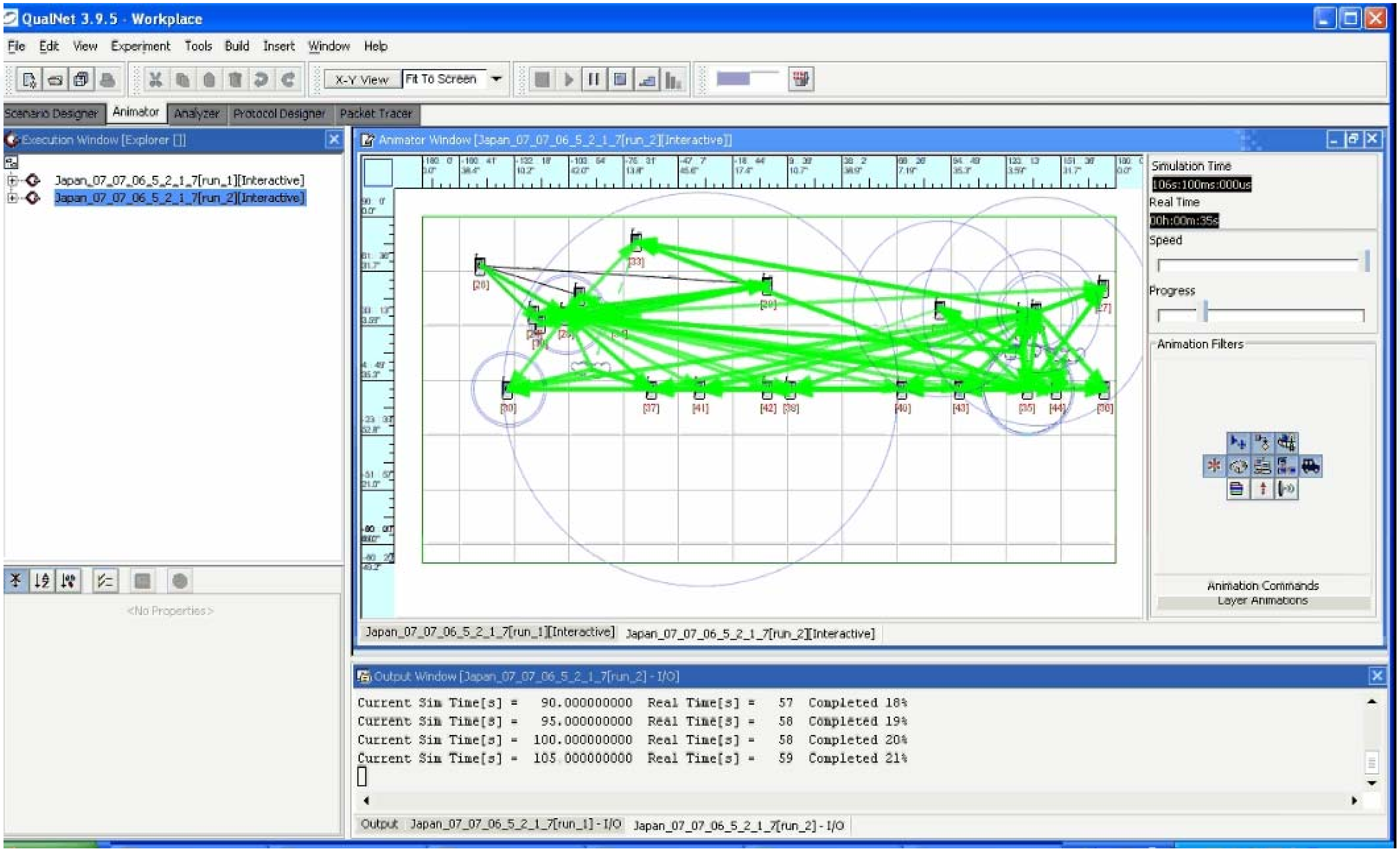
STK Scenario



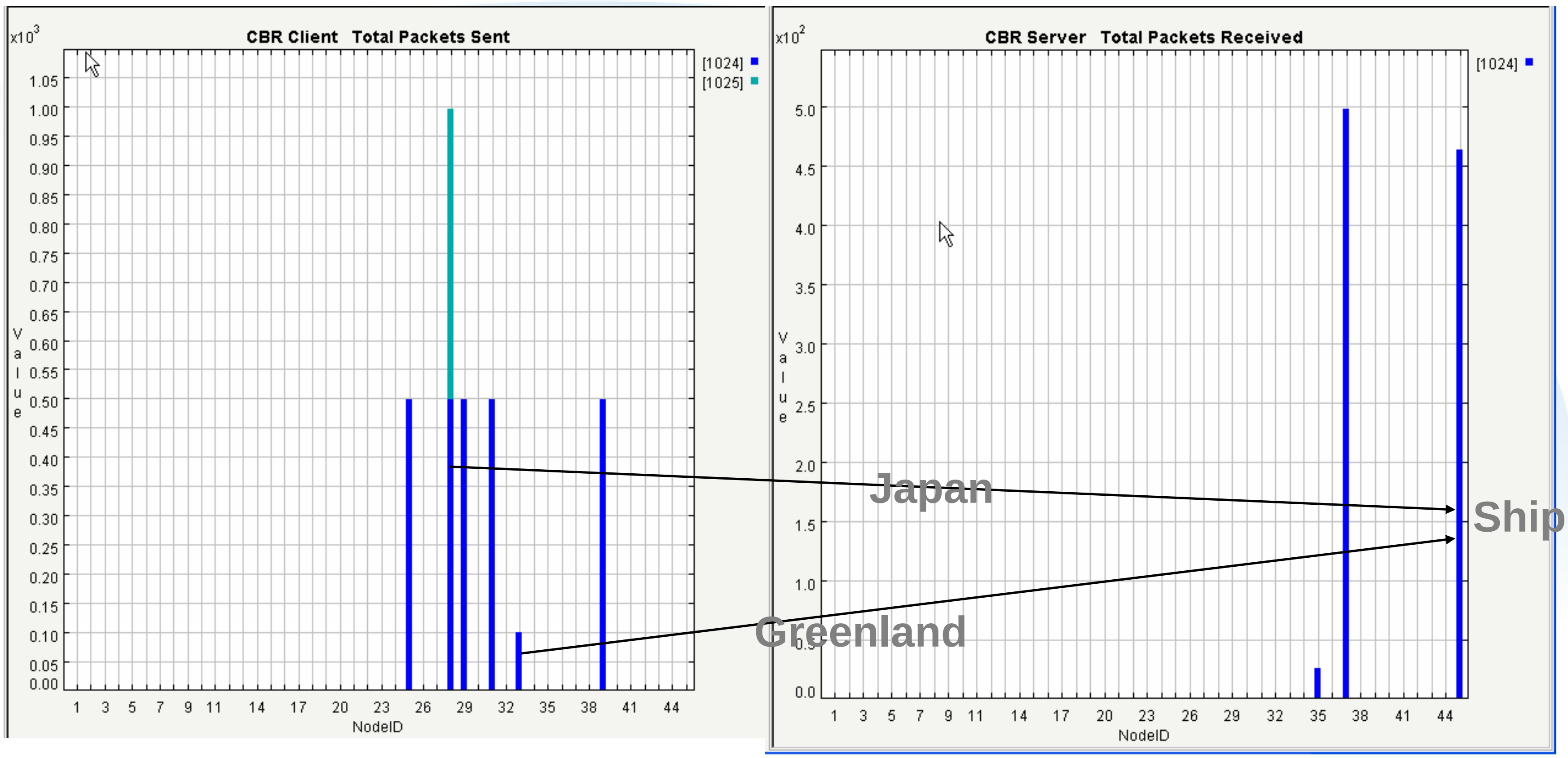
Scenario Export to QualNet



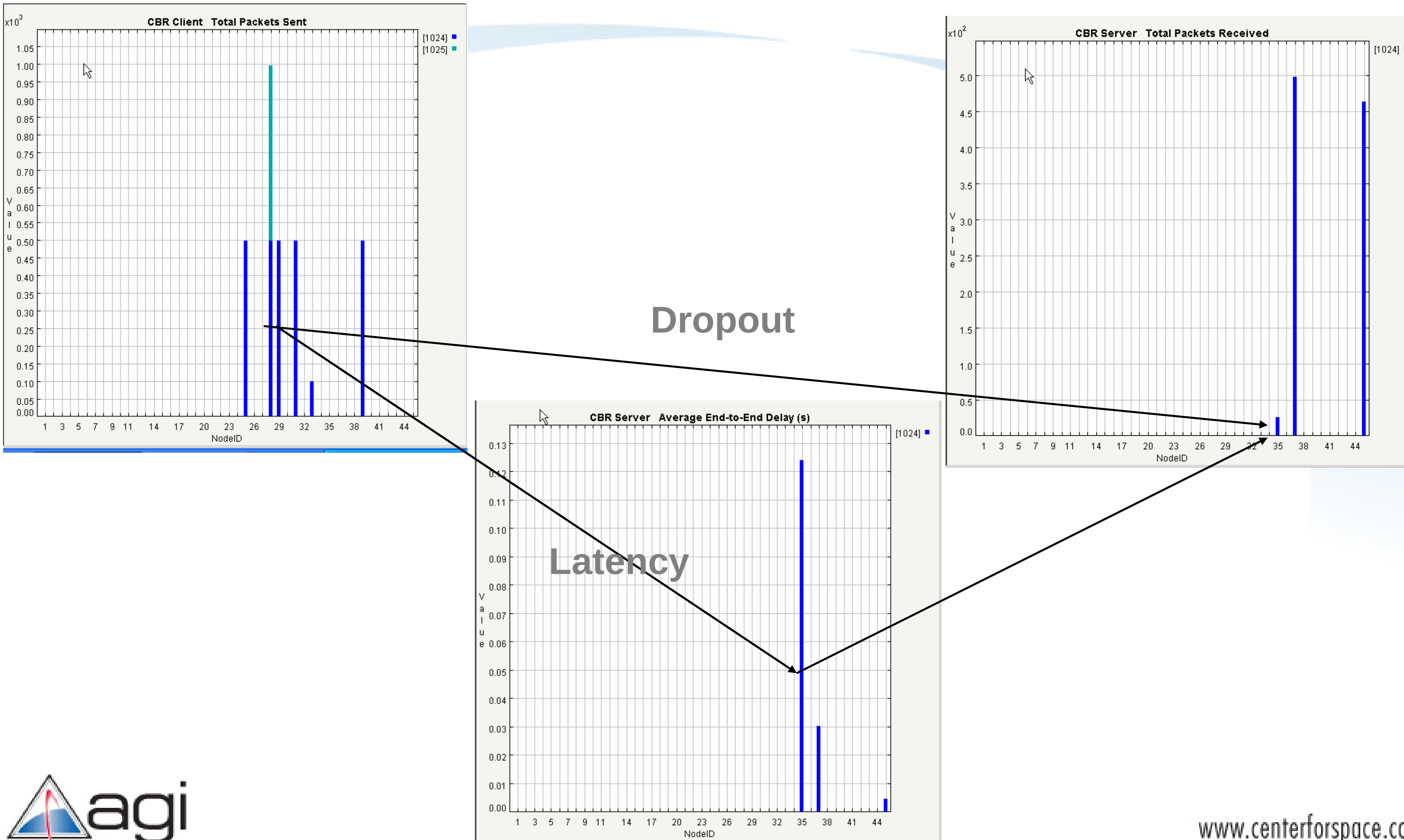
Qualnet Execution



1100 Packets Sent, 460 Packets Received



Ship to Satellite Dropout and Latency



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State Of Development And Research

- Tools maturing for robust physical layer and higher layer simulation
- Emerging capability for protocol stack optimization for sparse, mobile, ad hoc networks
- STK/NetSim limitations recognized
- BSQ dedicated interface paradigm developed
  - More efficient and problem tuned than HLA, DIS, or other standards
- Interfaces will be available to all licensed for STK and a communication network simulation environment (QualNet, OPNET, etc.)