JiST:
Java in Simulation Time

for

Scalable Simulation of Mobile Ad hoc Networks

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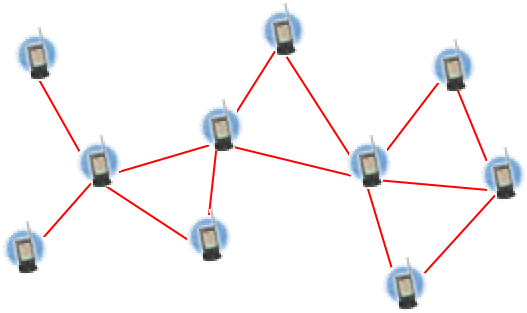
simulation scalability is important

- discrete event simulations are useful and needed
- but, most published ad hoc network simulations
  - lack network *size* ~250 nodes; or
  - compromise *detail* packet level; or
  - curtail *duration* few minutes; or
  - are of sparse *density* $<10/km^2$

  i.e. limited simulation scalability



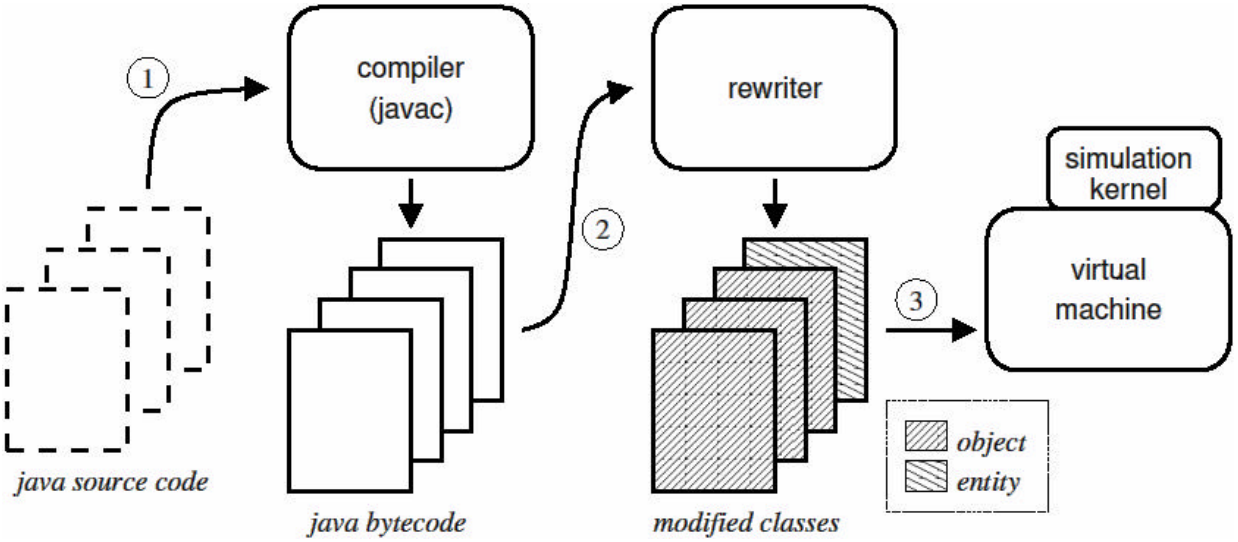
- A university *campus*
  - 30,000 students, < 4 km^2, 1 device/student
- The United States *military*
  - 100-150,000 troops, clustered
- Sensor networks, smart dust, Ubicomp
  - Many thousands of wireless devices in environment

Simulation scalability is important

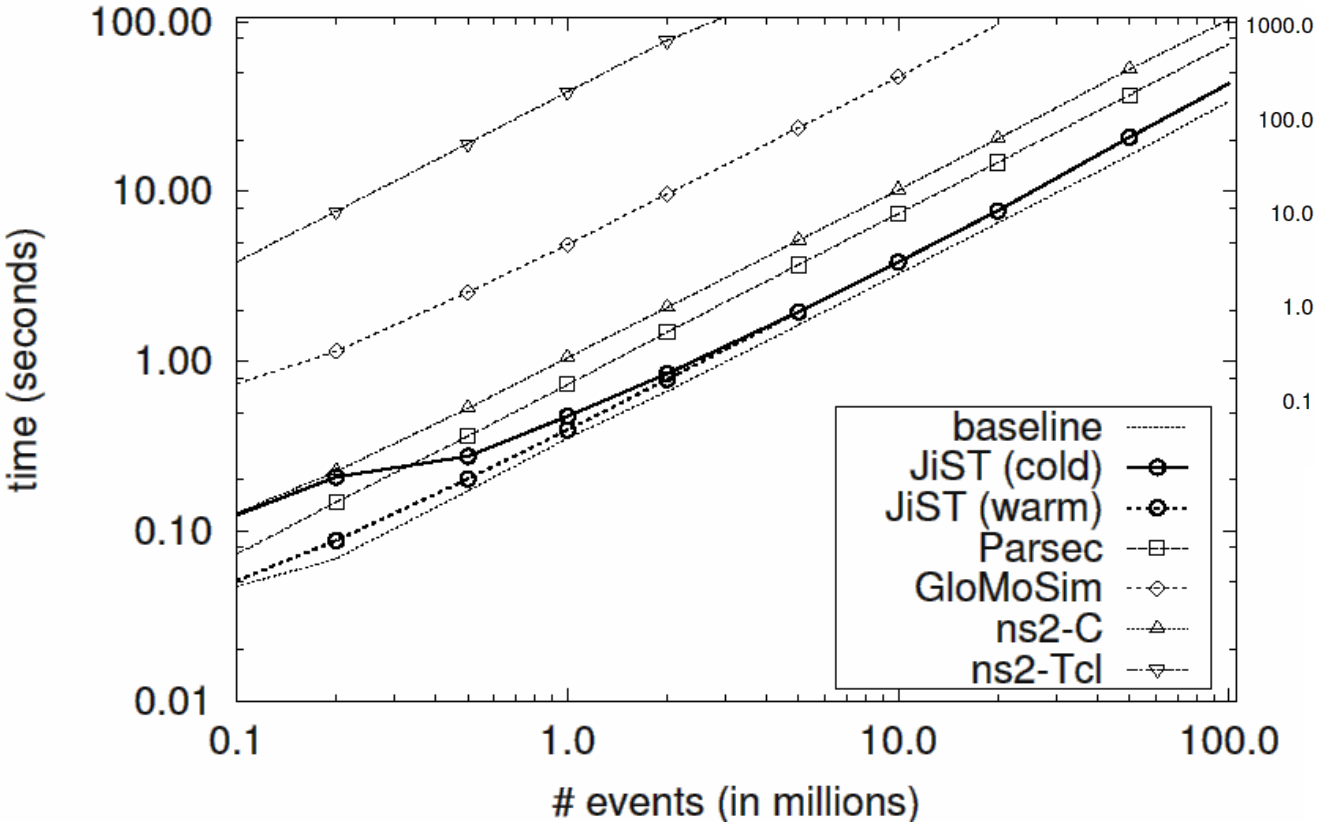
JiST – Java in Simulation Time

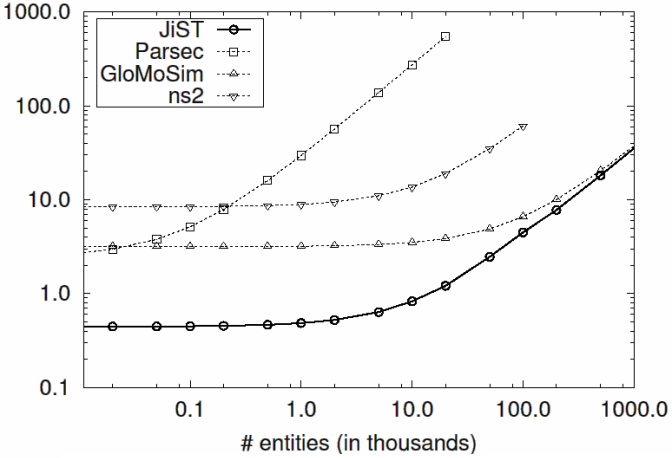
- JiST *extends* Java object model and execution semantics
- … to run discrete event simulations: *transparently*
  - simulations written in plain Java
  - compiled classes are modified at load time

  and *efficiently*
  - reduces serialization and context-switching overhead
  - allows parallel and speculative simulation execution
- Merges modern language and simulation semantics
  - run Java programs in simulation time



performance: event throughput (and memory)





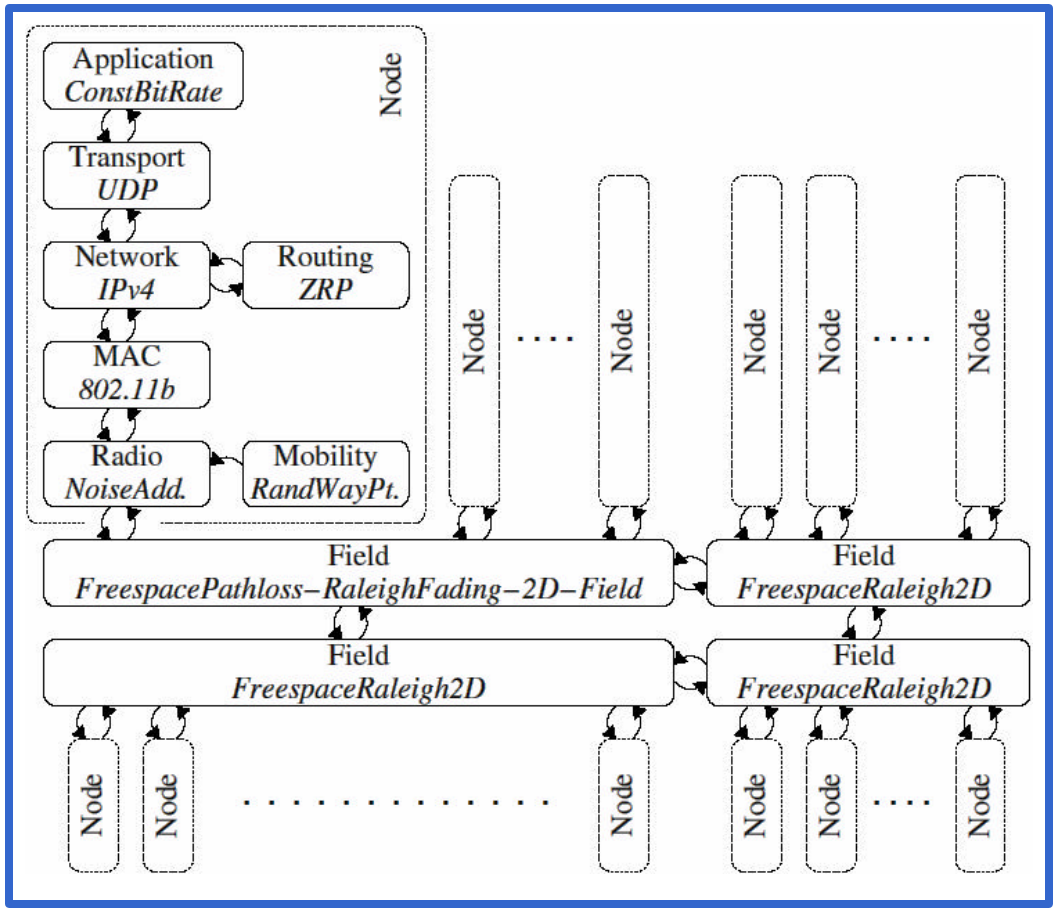
5×10^6 events	time (sec)	vs. baseline	vs. JiST
baseline	1.640	1.0x	0.8x
JiST	**1.957**	**1.2x**	**1.0x**
Parsec	3.705	2.3x	1.9x
ns2-C	5.151	3.1x	2.6x
GloMoSim	23.720	14.5x	12.1x
ns2-Tcl	160.514	97.9x	82.0x

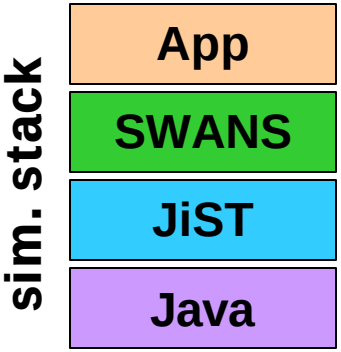
# events	JiST	GloMoSim	Ratio
10^5	0.044s	0.435s	10%
10^6	0.262s	2.938s	9%
10^7	2.301s	28.04s	8%
10^8	22.48s	278.4s	8%

serial throughput increase of 12x

SWANS

- **Scalable Wireless Ad hoc Network Simulator**
  - **runs standard Java network applications**
  - **allows vertical *and* horizontal aggregation**

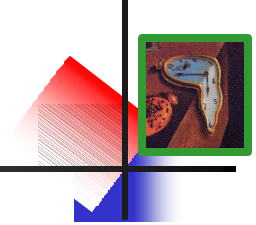




	files	classes	lines
JiST	26	69	9548
SWANS	61	127	13999
Other	18	30	2415
	105	**236**	**25962**

- shorter and simpler than GloMoSim and ns2
- developed in <3 months

performance: SWANS

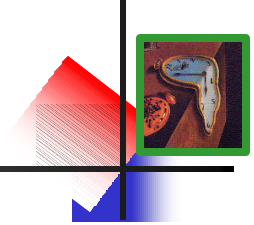


- simulation configuration
  - field — 5x5km²; free-space path loss; no fading
  - mobility — random waypoint: v=2-5m, p=10s
  - radio — additive noise; standard power, gain, etc.
  - link — 802.11b
  - network — IPv4
  - transport — UDP
  - application — heartbeat neighbor discovery
- ran on:
  - PIII 1.1GHz laptop
  - only 384 MB RAM
  - Sun JDK 1.4.2
- memory consumption:
  - 1.2KB per simulated node!

	nodes		
	1,000	10,000	100,000
ns2	☑	☒	☒
Glomo	☑	☑	☒
SWANS	☑	☑	☑

backup slides

existing alternatives



ns2 **is the *gold standard***

- **C++ with Tcl bindings, O(n^2)**
- **used extensively by community**
- **written for TCP simulation**
- **modified for ad hoc networks**
- **processor and memory intensive**
- **sequential; max. ~500 nodes**

PDNS **– parallel distributed ns2**

- **event loop uses RTI-KIT**
- **needs fast inter-connect**
- **distribute memory, ~1000 nodes**

OpNet **– popular commercial option**

- **good modeling capabilities**
- **poor scalability**

custom-made **simulators**

- **fast, specialized computation**
- **lack sophisticated execution and also *credibility***

GloMoSim

- **implemented in Parsec, a custom C-like language**
- **entities are memory intensive**
- **requires "node aggregation," which imposes conservative parallelism, loses Parsec benefits**
- **shown ~10,000 nodes on NUMA machine (SPARC 1000, est. $300k)**

SWAN

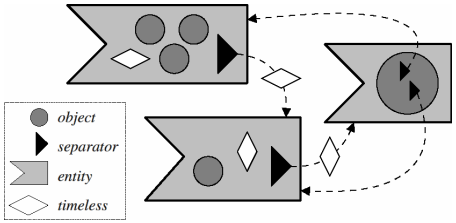
- **implemented atop the parallel, distributed DaSSF framework**
- **similar to GloMoSim**

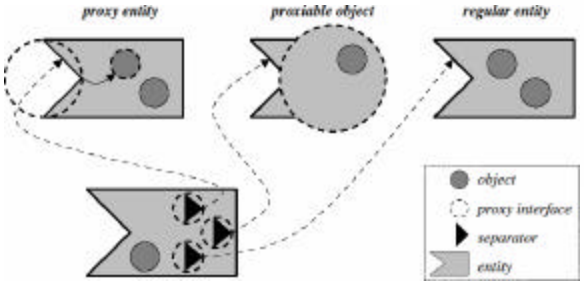
Simulation approaches

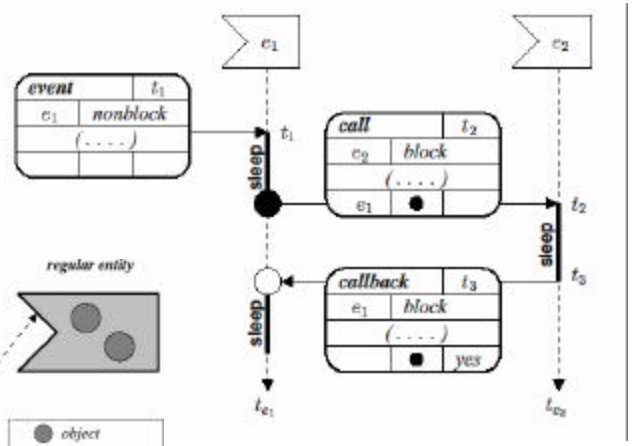
- **languages (e.g. Parsec, Simula)**
- **libraries (e.g. Yansl, Compose)**
- **systems (e.g. TWOS, Warped)**

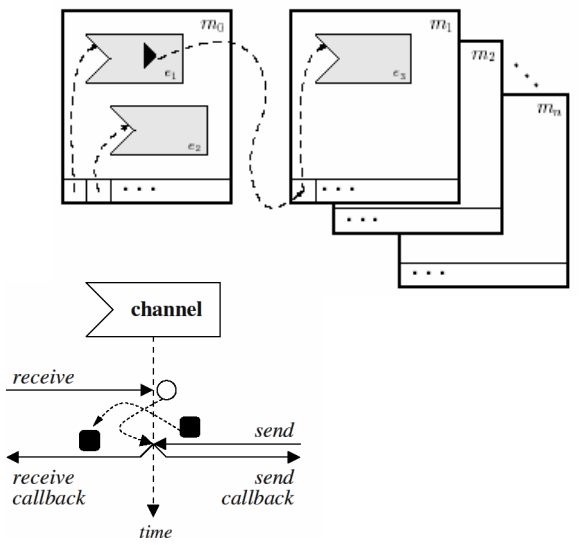
a lot more than simulation time

- **timeless objects**: pass-by-reference to avoid copy
- **proxy entities**: interface-based entity creation
- **continuations**: call and callback, blocking methods
- **concurrency**: channel, threads, monitors, locks...
- **distribution**: separators track entities across machines
- **scripting**: embed engines for Java, Python, Tcl, etc...





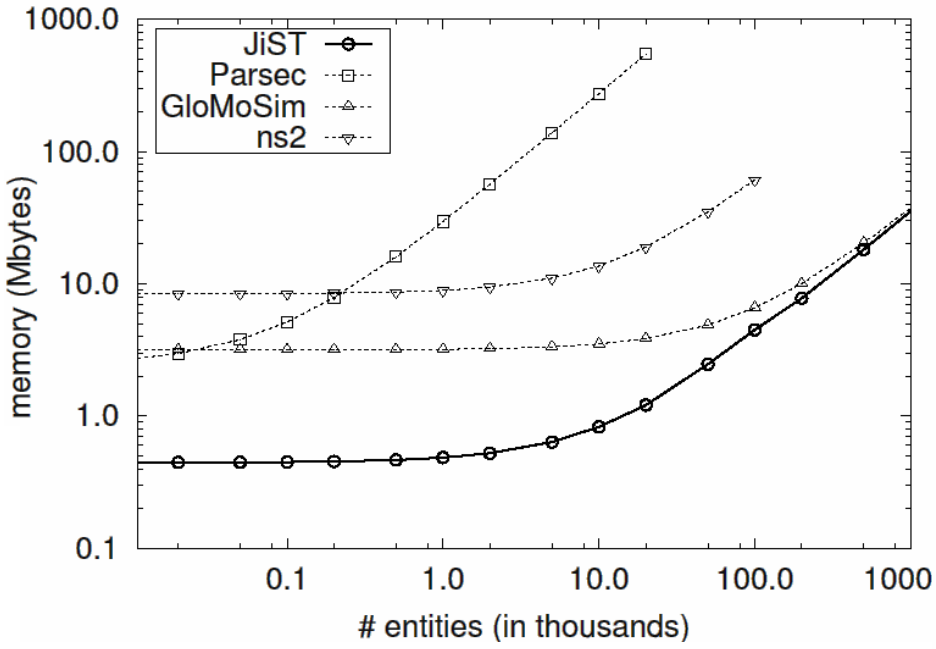


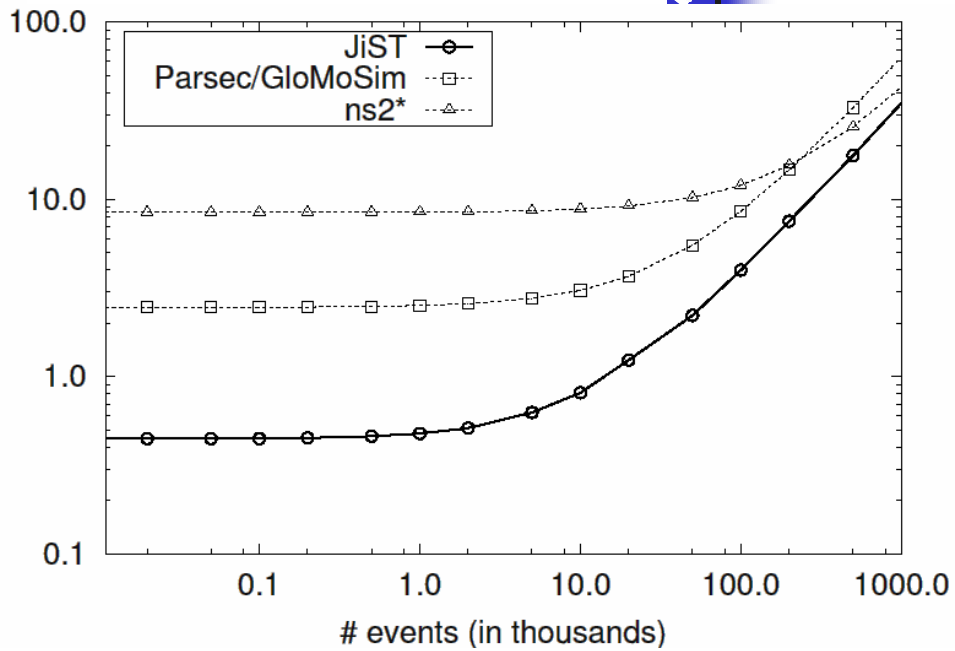


benefits of the jist approach

- more than just scalability.
- application-oriented benefits
  - type safety — source-target statically checked
  - event types — not required (implicit)
  - event structures — not required (implicit)
  - debugging — dispatch location and state available
- language-oriented benefits
  - garbage collection — memory savings, cleaner code
  - reflection — script-based configuration of simulations
  - safety — fine granularity of isolation
  - Java — standard language, compiler, runtime
- system-oriented benefits
  - IPC — no context switch; no serialization
  - Java kernel — cross-layer optimization
  - robustness — no memory leaks, no crashes
  - rewriting — no source-code access required
  - concurrency — supports parallel and speculative execution
  - distribution — provides a single system image abstraction
- hardware-oriented benefits
  - cost — COTS hardware, clusters (NOW)
  - portability — pure Java; “runs everywhere”

performance: memory overhead





memory	entity	event	10K nodes sim.
JiST	**36 B**	**36 B**	**21 MB**
GloMoSim	36 B	64 B	35 MB
ns2	544 B	36 B*	72 MB*
Parsec	28536 B	64 B	2885 MB

	Memory	Limit
JiST	36 bytes	> 10^6 entities
Parsec	28536 bytes	~ 10^4 entities

JiST scales to more entities per process