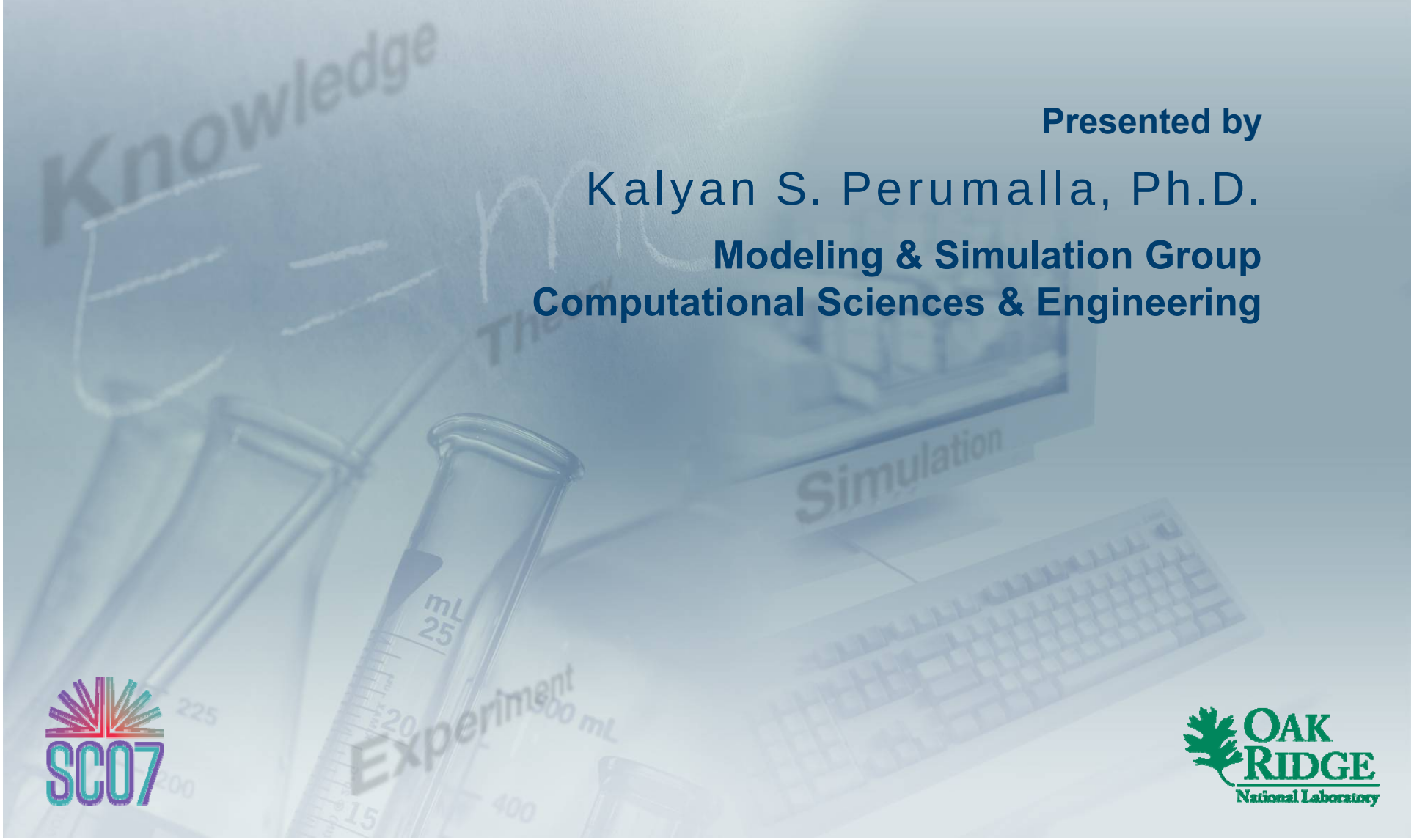
Parallel Discrete Event Simulation (PDES) at ORNL



Presented by

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Computational Sciences & Engineering

SC07

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PDES: Selected application areas

- **Network simulation**
  - Internet protocols, security, P2P designs, …
- **Traffic simulation**
  - Emergency planning/response, environmental policy analysis, urban planning, …
- **Social dynamics simulation**
  - Operations planning, foreign policy, marketing, …
- **Sensor simulations**
  - Wide area monitoring, situational awareness, border surveillance, …
- **Organization simulations**
  - Command and control, business processes, …

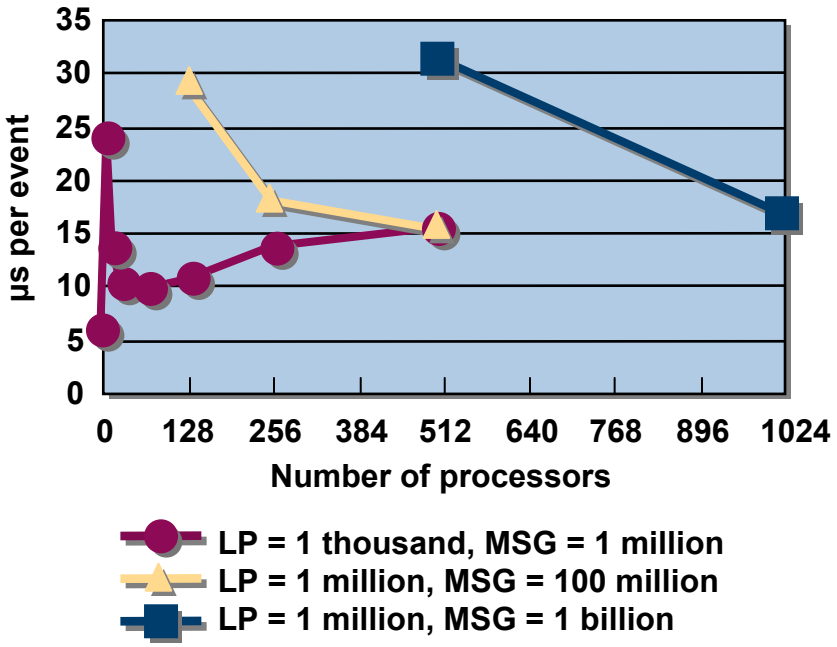
High-performance PDES kernel requirements

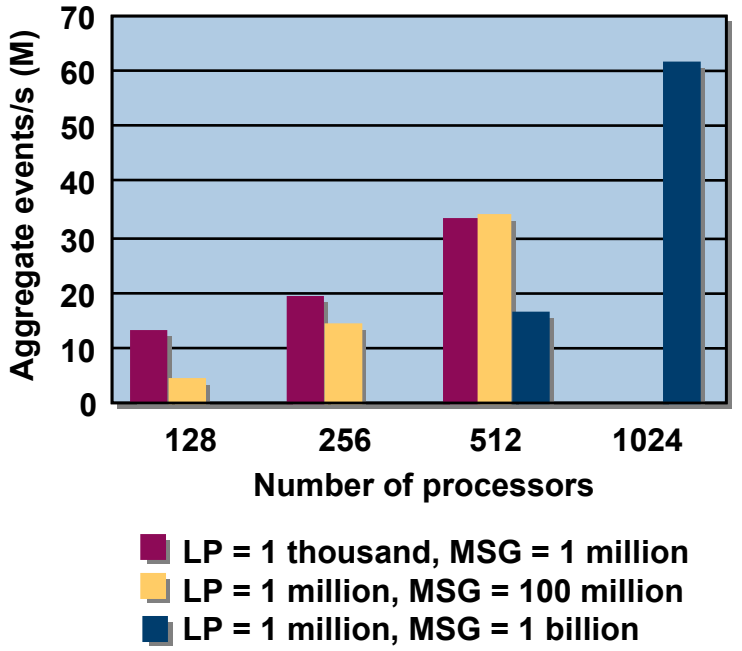
- **Global time synchronization**
  - **Total time-stamped ordering of events**
  - **Paramount for accuracy**
- **Fast synchronization**
  - **Scalable, application-independent, time-advance mechanisms**
  - **Critical for real-time and as-fast-as-possible execution**
- **Support for fine-grained events**
  - **Minimal overhead relative to event processing times**
  - **Application computation is typically only 5 µs to 50 µs per event**
- **Conservative, optimistic, and mixed modes**
  - **Need support for the principal synchronization approaches**
  - **Useful to choose mode on per-entity basis at initialization**
  - **Desirable to vary mode dynamically during simulation**
- **General-purpose API**
  - **Reusable across multiple applications**
  - **Accommodates multiple techniques**
    - **Lookahead, state saving, reverse computation, multicast, etc.**

μsik—unique PDES "micro-kernel"

Unique mixed-mode kernel
- The only scalable mixed-mode kernel in the world
- Supports conservative, optimistic, and mixed modes in a single kernel

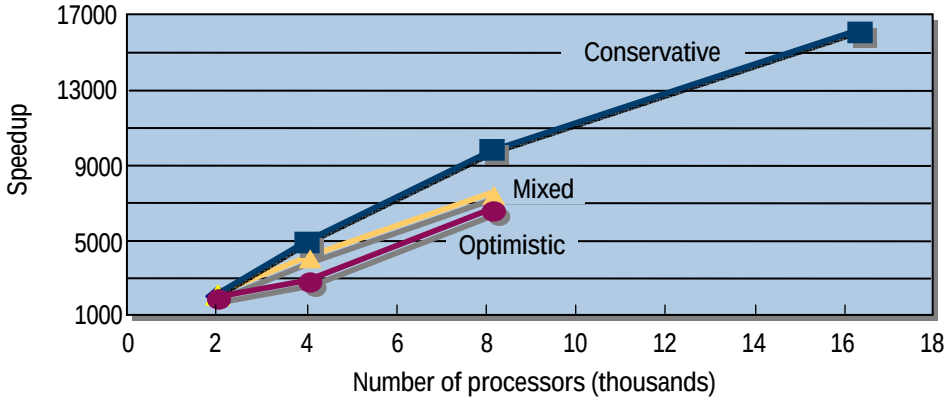
Used in a variety of applications
- DES-based vehicular traffic models
- DES-based plasma physics models
- DES-based neurological models
- Largest Internet simulations

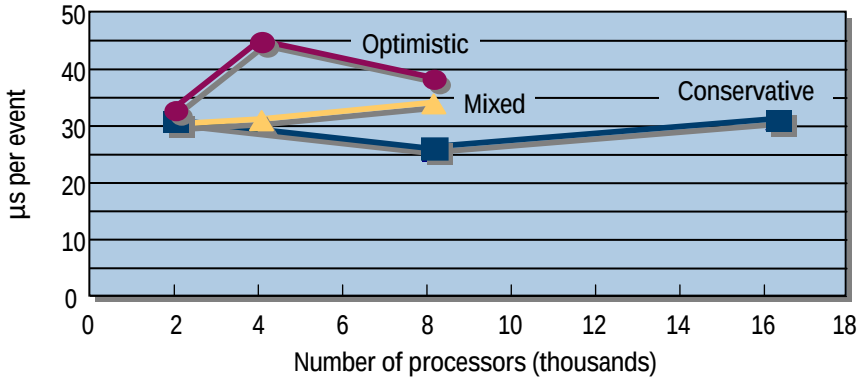


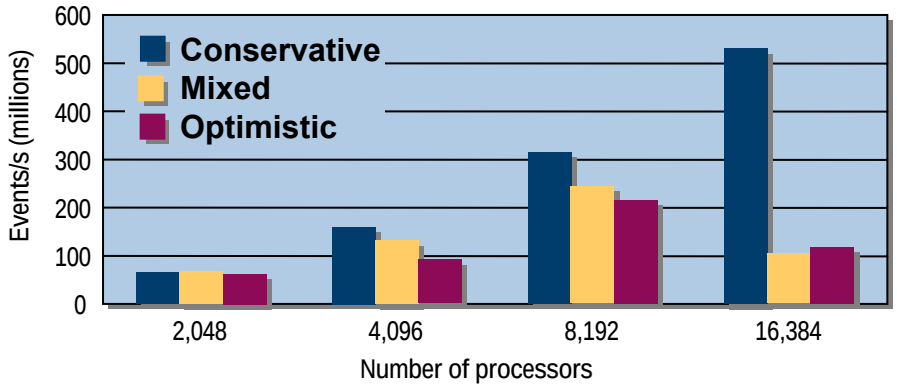


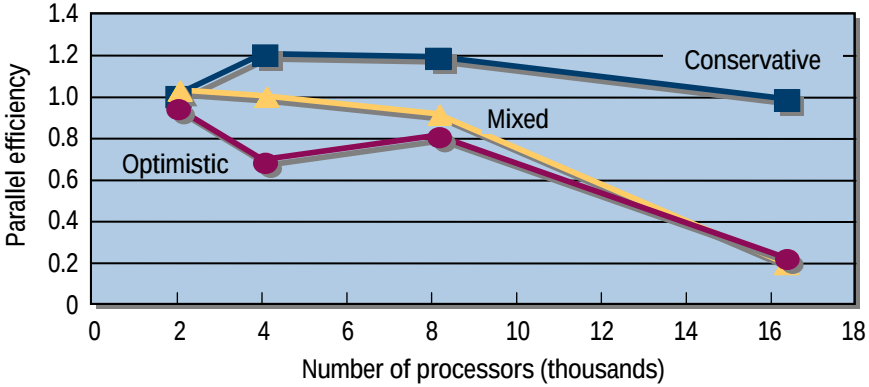
- **Some recent results of fine-grained PDES benchmark (phold)**
- **Among the largest/fastest scalability results in parallel discrete event simulation**

μsik scaled to more than 10^4 processors



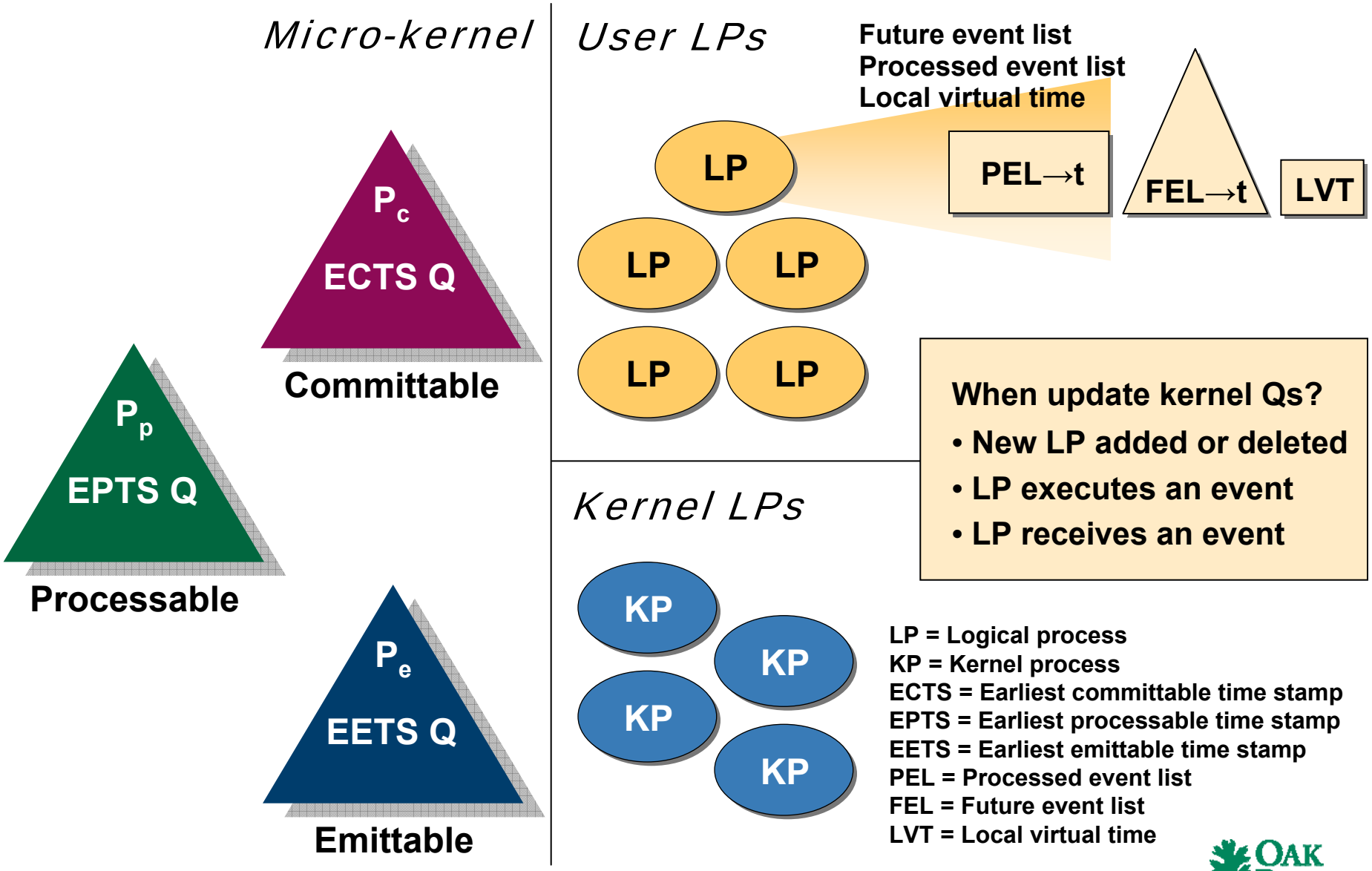




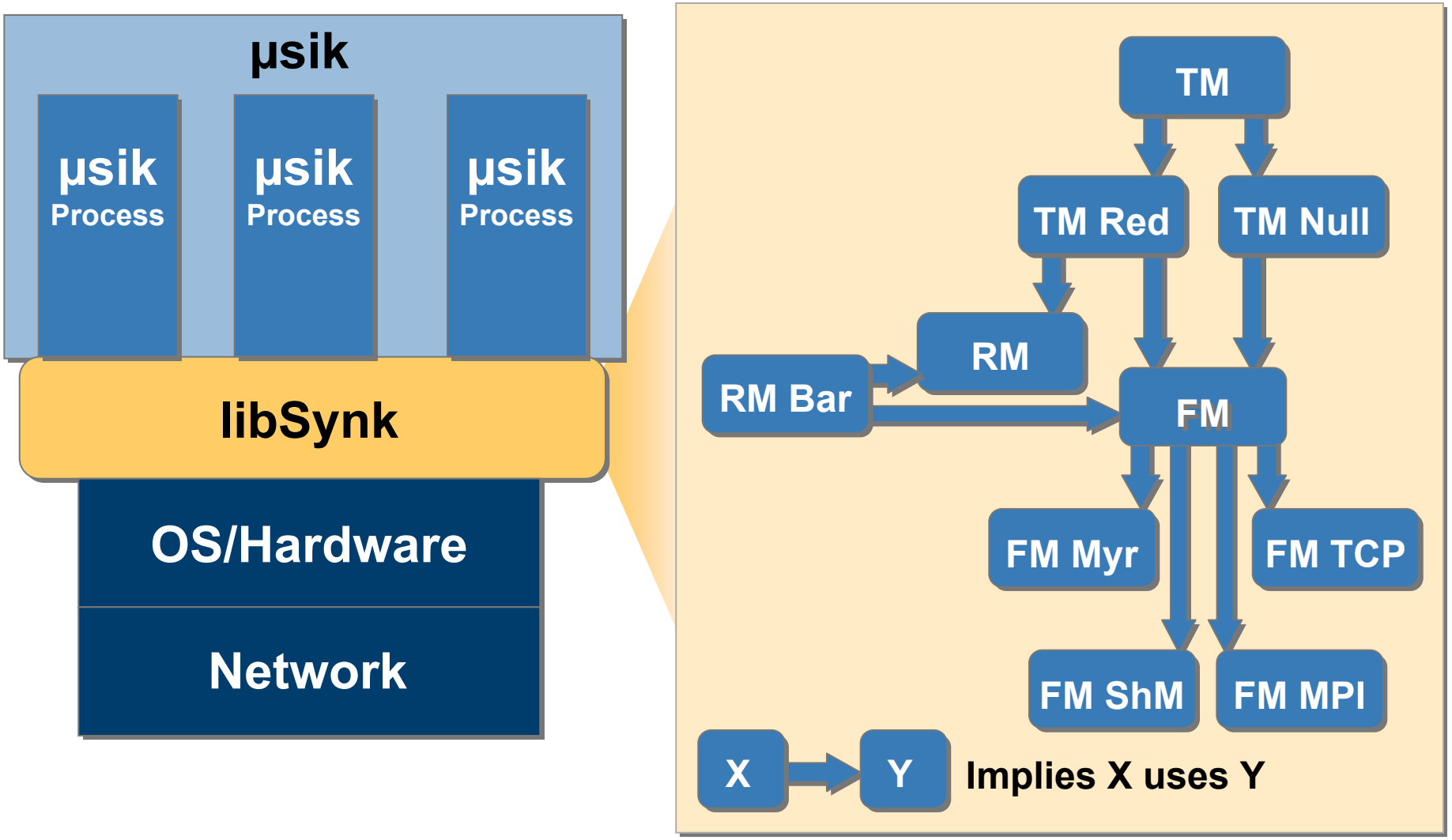


- **Some recent results of** fine-grained **PDES benchmark**
  - **On Blue Gene Watson (BGW) at IBM TJ Watson Research Center**
  - **Well-known PHOLD benchmark, with 1 million logical processes, 10 million pucks**
- **The largest and fastest scalability results in PDES recorded to date**

µsik micro-kernel internals



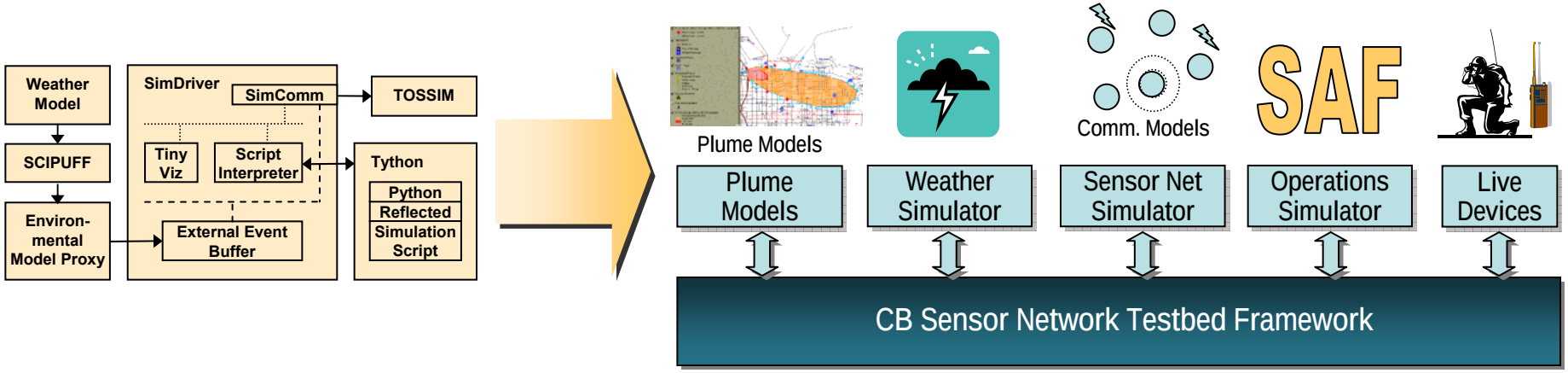
libSynk: µsik's synchronization core



µsik micro-kernel capabilities

- **µsik is currently able to support the following:**
  - **Lookahead-based conservative and/or optimistic execution**
  - **Reverse computation-based optimistic execution**
  - **Checkpointing-based optimistic execution**
  - **Resilient optimistic execution (zero rollbacks)**
    - **Constrained, out-of-order execution**
    - **Preemptive event processing**
  - **Any combinations of the above**
  - **Automated, network-throttled flow control**
  - **User-level event retraction**
  - **Process-specific limits to optimism**
  - **Dynamic process addition/deletion**
  - **Shared and/or distributed memory execution**
  - **Process-oriented views**
- **It accommodates addition of the following:**
  - **Synchronized multicast**
  - **Optimistic dynamic memory allocation**
  - **Automated load-balancing**

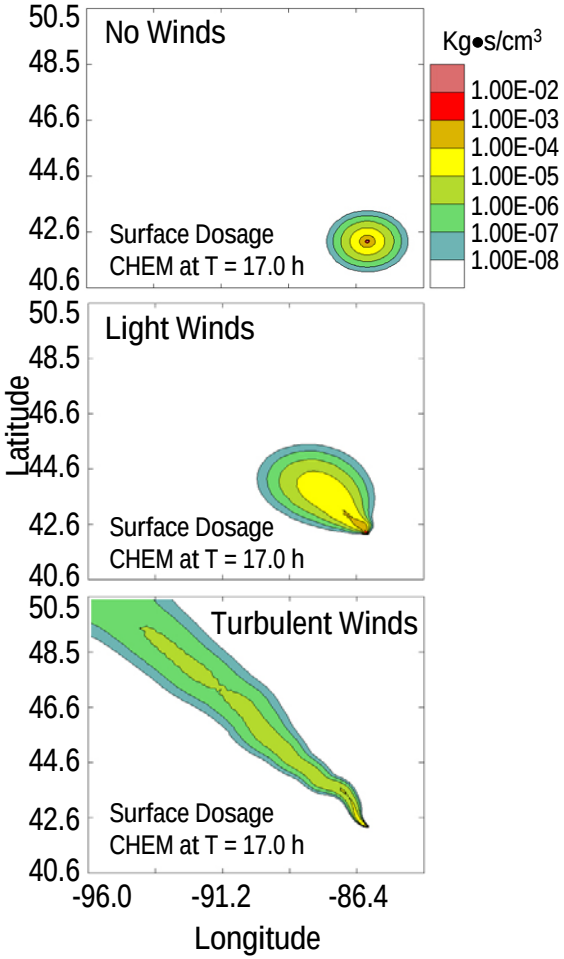
SensorNet: Parallel simulation/ immersive test-bed

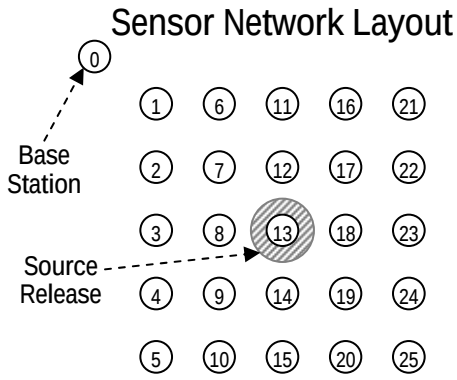


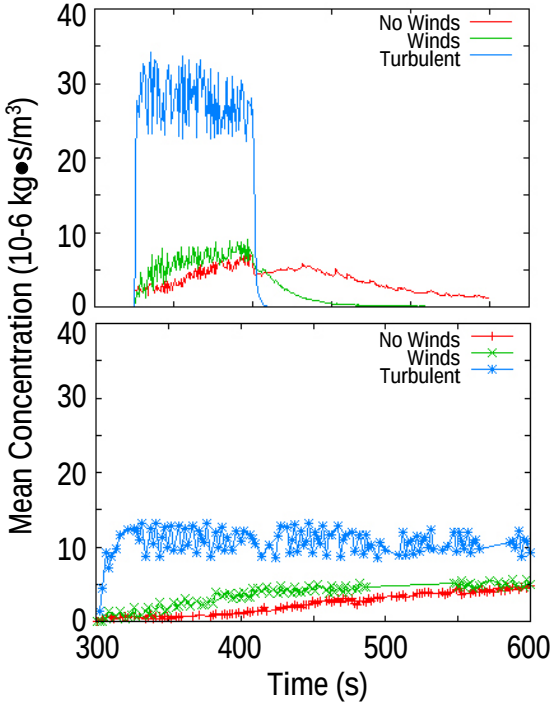
Current **Envisioned**

- **Seamless integrated testbed to incorporate a variety of important simulations, stimulations, and live devices**
- **Achieves unified capabilities and significant fidelity for test and evaluation of CB sensor device-based designs, concepts, and operations**

SensorNet: Simulation-based analysis for plume tracking





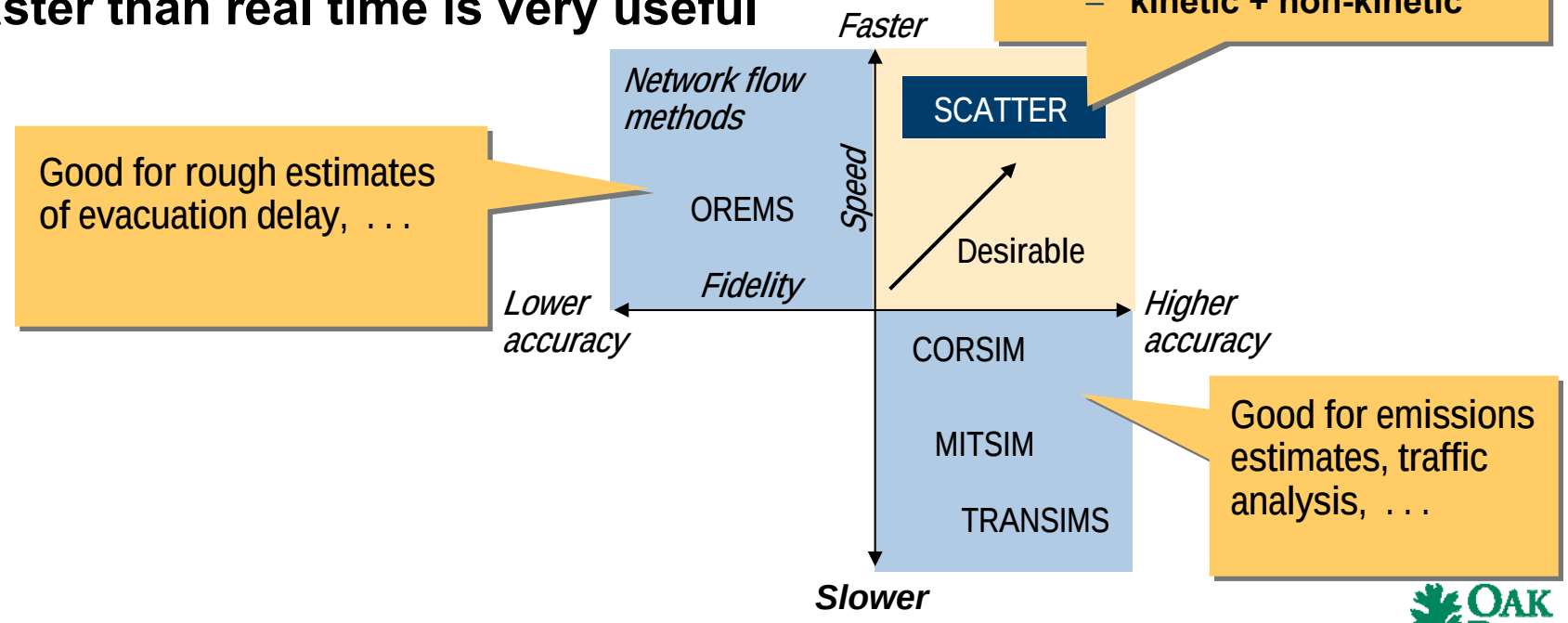


- **Environmental phenomenon exhibits high variability.**
- **Phenomenon drives the sensor network's computation and communication.**
- **Trace gathered at base station of sensed phenomenon reflects high variability.**
- **Communication effects induce unpredictable gaps in series.**
- **Accurate, integrated simulation of phenomenon and communication captures complex interdependencies.**

SCATTER: Ultra-scale PDES-based mobility simulations

- **Scalable tool for transportation and energy/event/emergency research**
- **Regional scale: multiple states**
  - **10^6–10^7 intersections**
- **Current tool capabilities**
  - **At most 10^4 intersections**
- **Faster than real time is very useful**

Our approach: SCATTER
- **DES models**
  - **vs time-stepped**
- **Parallel execution**
  - **vs sequential**
- **Scalability to high-performance computing**
  - **10^2–10^3 CPUs**
- **Important behaviors**
  - **kinetic + non-kinetic**



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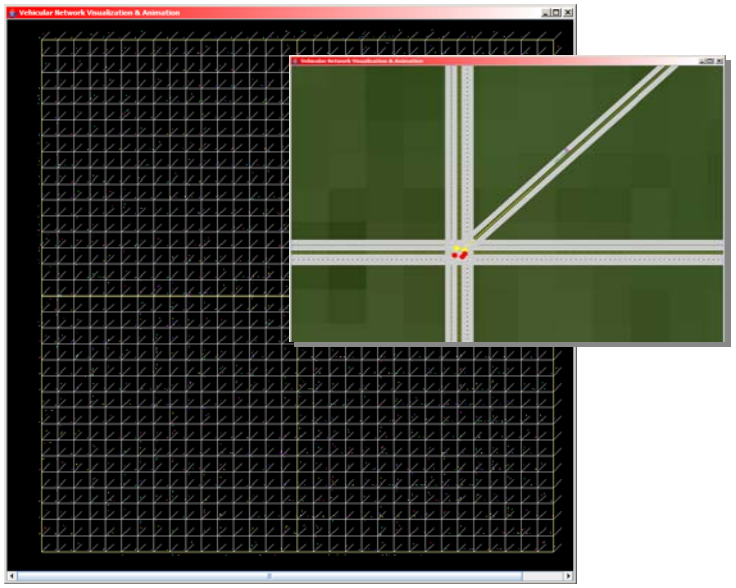
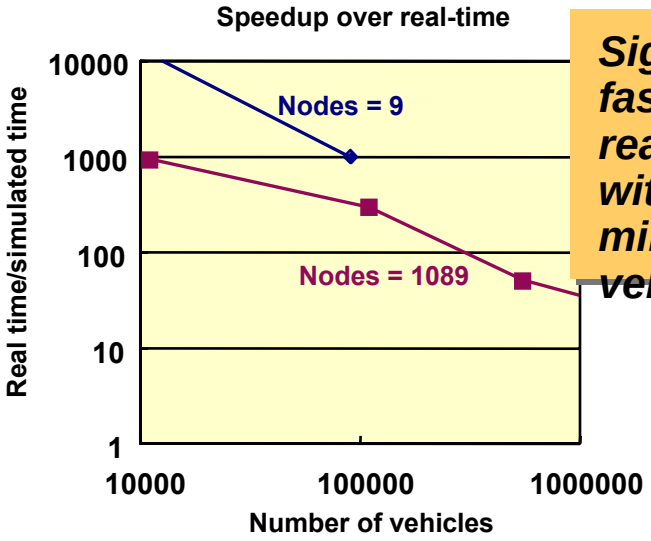
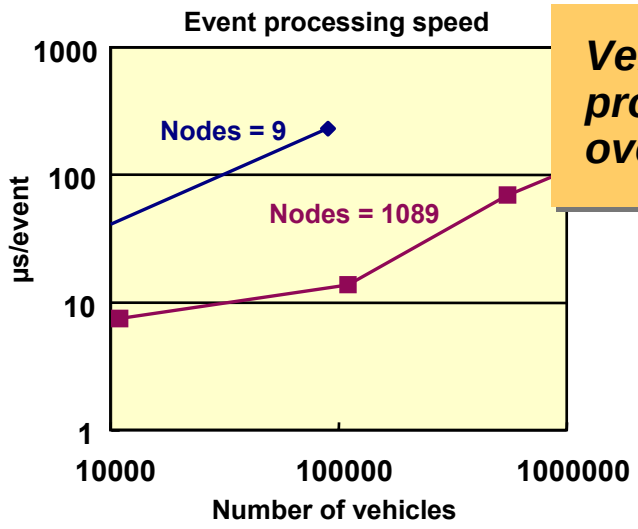
SCATTER: Benchmark performance

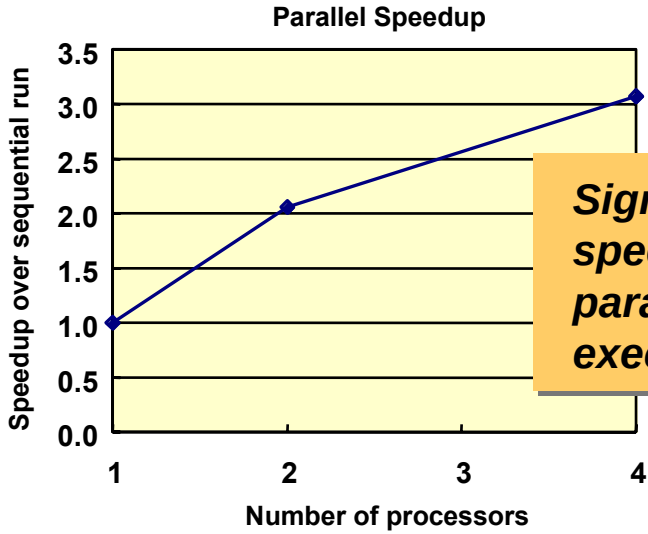




Significantly faster than real time with 1 million vehicles!



Very low event processing overhead (ms)!



Significant speedup with parallel execution!

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