Multi-client LAN/WAN Performance Analysis of Ninf: a High-Performance Global Computing System

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http://ninf.etl.go.jp/

Towards Global Computing Infrastructure

Rapid increase in speed and availability of network

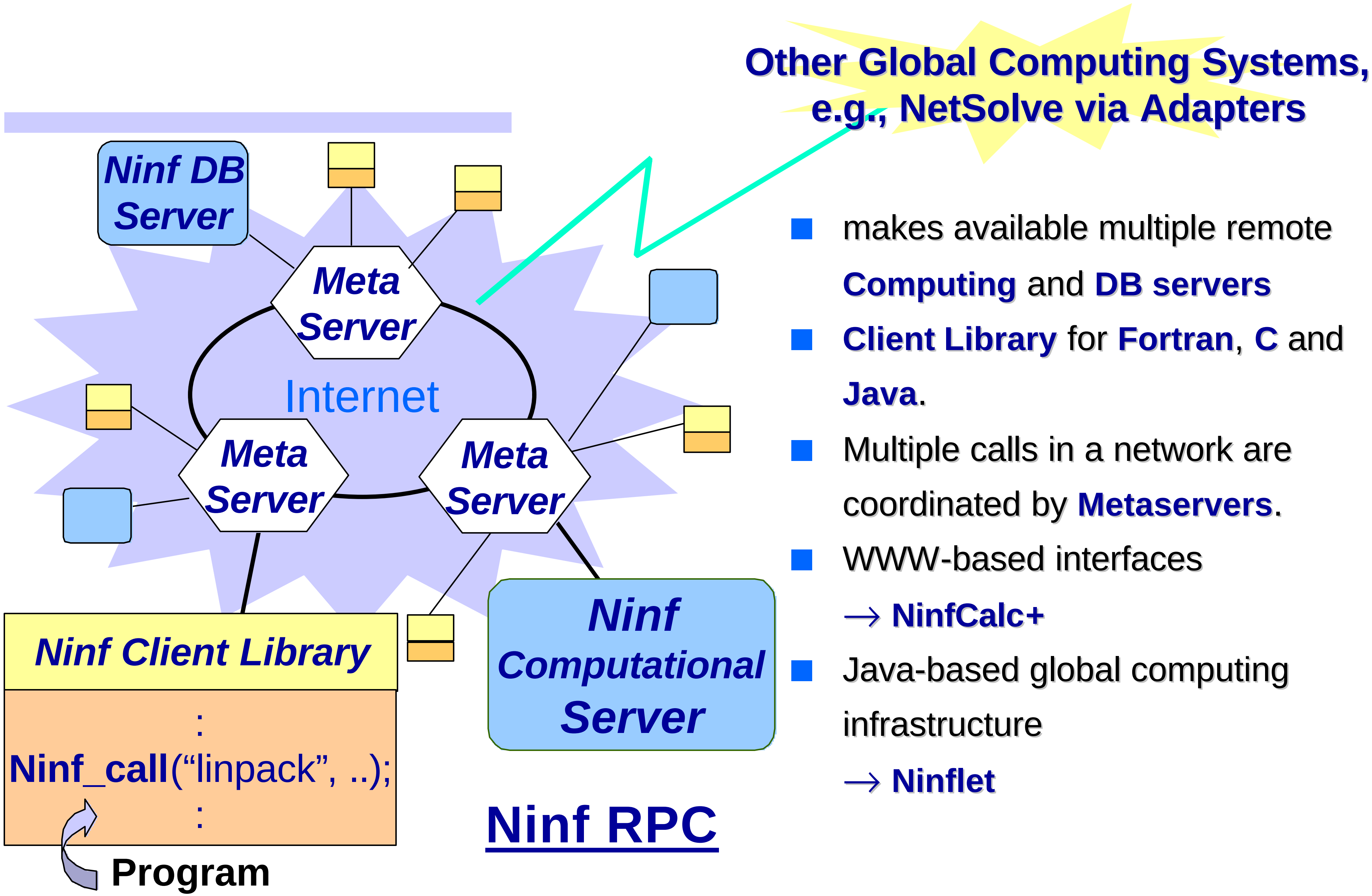
→ **Computational and Data Resources** are collectively employed to solve large-scale problems.

Global Computing (Metacomputing, The "Grid")

Ninf **(Network Infrastructure for Global Computing)**

c.f., ***NetSolve****,* ***Legion****,* ***RCS****,* ***Javelin****,* ***Globus*** *etc.*

Overview of Ninf



Ninf RPC

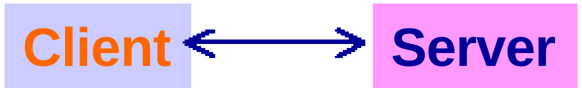
- makes available multiple remote **Computing** and **DB servers**
- **Client Library** for **Fortran**, **C** and **Java**.
- Multiple calls in a network are coordinated by **Metaservers**.
- WWW-based interfaces
  → **NinfCalc+**
- Java-based global computing infrastructure
  → **Ninflet**

Issues of Global Computing systems

- **Communication Performance** (throughput, latency)
  - High latency → deterrent to performance?
- **Computing Server Selection**
  - Criteria to select servers?
  - Can supercomputers/MPPs be effectively shared by multiple remote clients? (Scheduling characteristics)
- **Sharing by Multiple clients**
  - Global computing servers on supercomputer/MPP OSes effectively handle multiple parallel tasks?
- **Remote Library Design and Reuse**
  - Allocate processors in a task-parallel / data-parallel manner ?
  - The right “remote library” design, decomposition, API, etc.

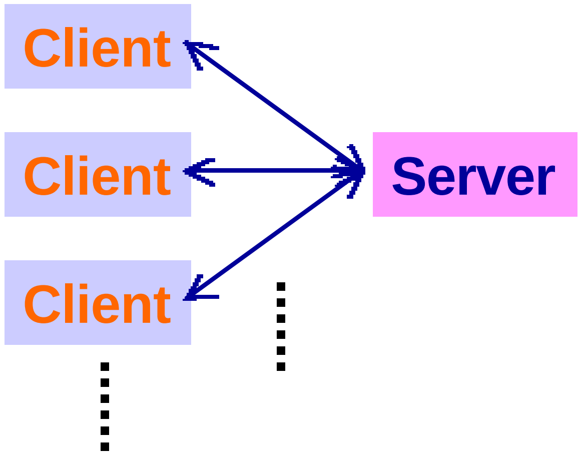
Outline of Benchmarks

- **Single-Client Benchmarks :**



  - **Ninf Baseline Performance** → **LAN, Linpack**

- **Multi-Client Benchmarks :**



  - **Communication Performance**

    → **LAN / WAN (Single-site / Multi-site)**
  - **Remote Library Design and Reuse**

    → **Task Parallel / Data Parallel**
  - **Robustness of Computational Server** (Cray J90)
  - **Ratio of Computation and Communication of Library**

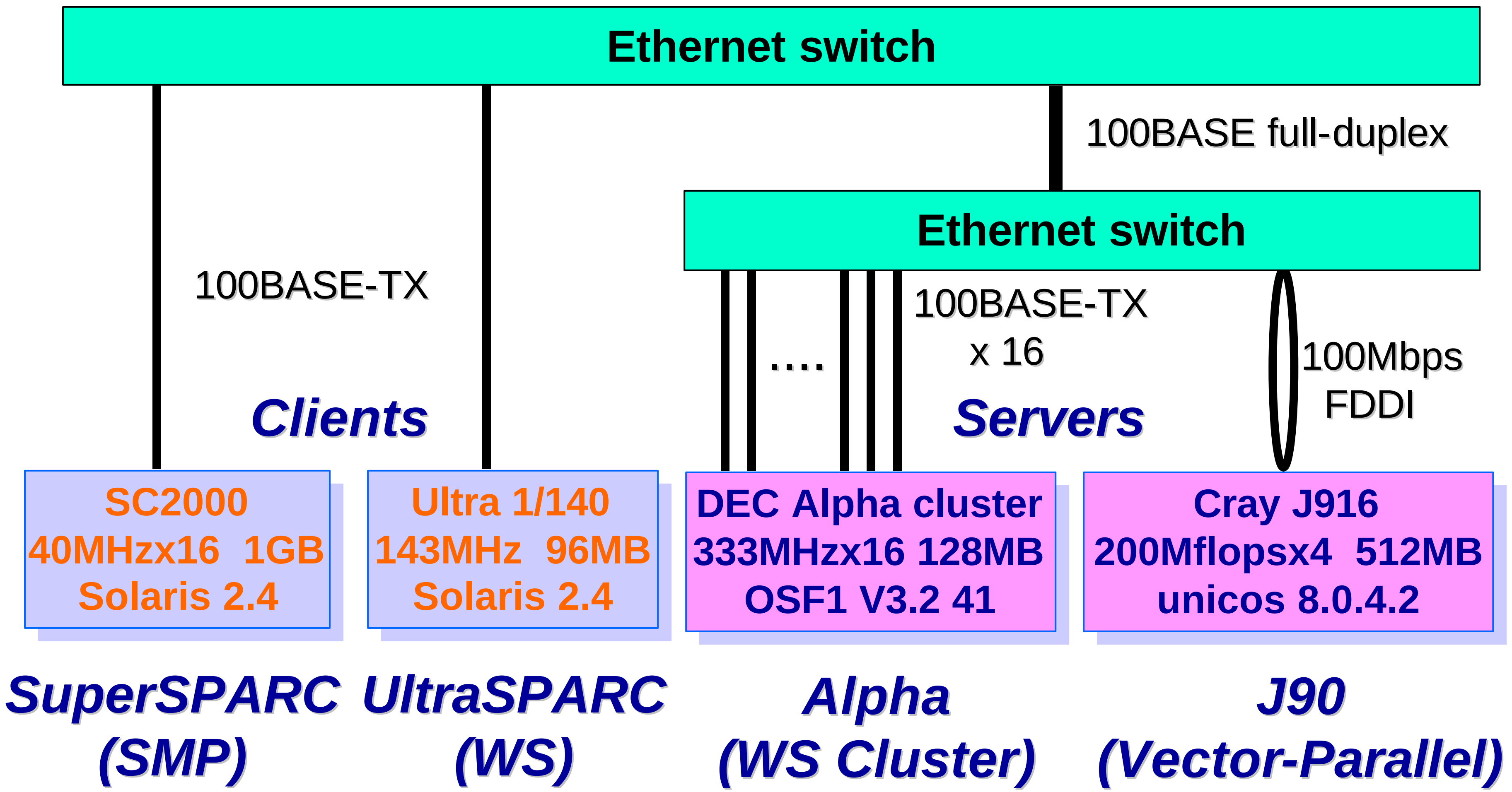
    → **Linpack / EP**

Benchmarks

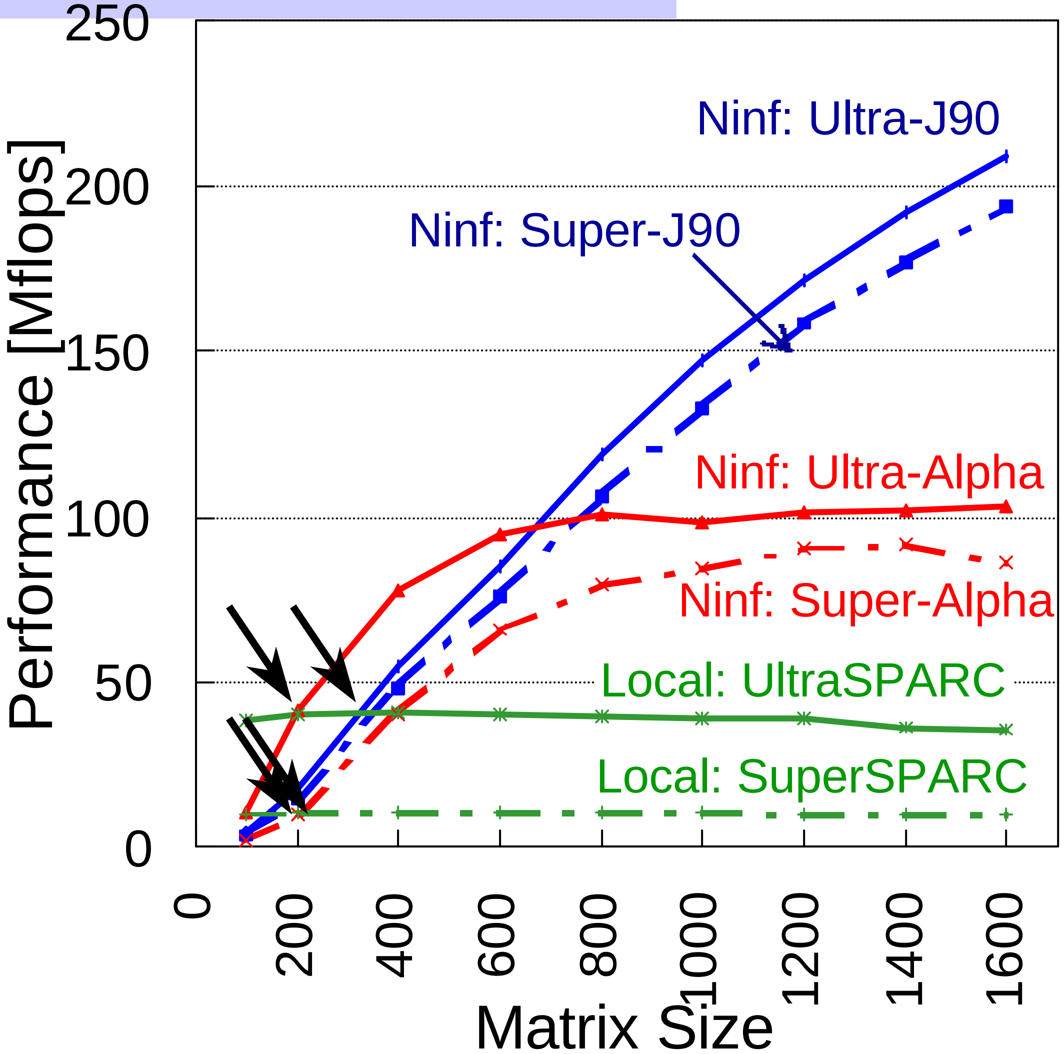
- **Linpack** : Gaussian Elimination
  - Computation: $2/3n^3 + 2n^2$ [flops]
  - Communication: $8n^2 + 20n + O(1)$ [bytes]
  - Performance: $(2/3n^3 + 2n^2)$ / **Elapsed Time** [flops]
- **EP (NASPB Kernel)** : Random Number Generation
  - Computation: 2^{n+1} [ops]
  - Communication: $O(1)$ [bytes]
  - Performance: 2^{n+1} / **Elapsed Time** [ops]

Elapsed Time = Communication + Computation

LAN Single-client Benchmarking Environment (at ETL)



LAN Single Client Linpack Results



- Ninf is faster than Local at *n* = 150〜300
- For Ninf_call to J90,

  Ninf performance is not saturated.

  (J90's Local achieves 600Mflops when *n*=1600)

  → Ninf performance quickly overtakes Local.
- The effects of client machine's performance difference are small.

Multi-client Benchmarks (LAN, WAN)

- **A Model Client Program**

  Linpack and **EP** are both repeatedly called:

  - Each client performs a Ninf_call on the interval of s seconds with probability p. $\rightarrow$ s = 3, p = 1/2 chosen.
  - Number of clients : c , problem size : n.

    $\rightarrow$ c = 1, 2, 4, 8, 16, **Linpack:** n = 600, 1000, 1400

    EP: n = 24(Sample)

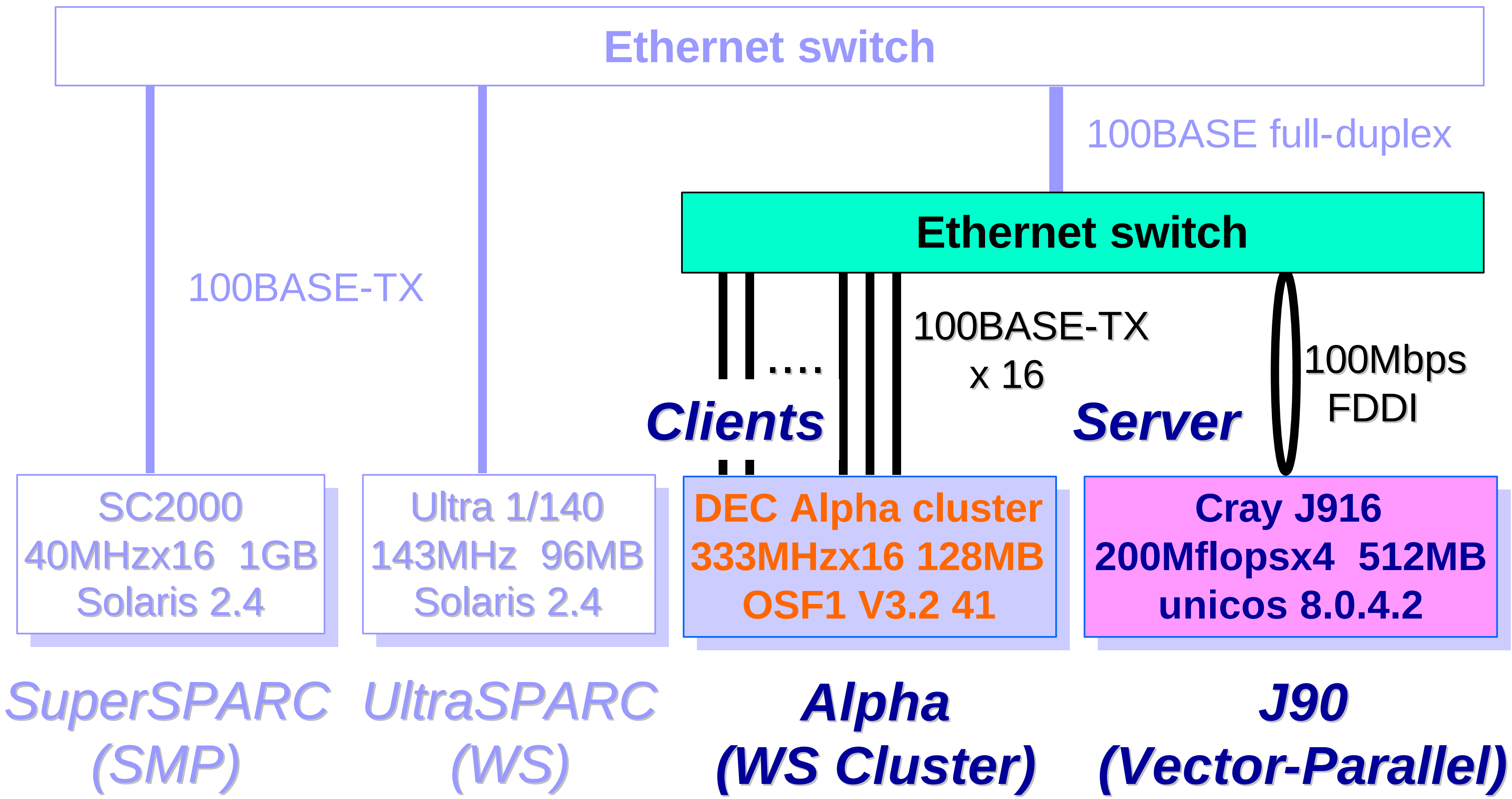
- **Parallel Processing on the server (J90 4PE)**
  - **Linpack**: **1PE ver.** --- Task Parallel

    1PE Execution and Parallel Processing

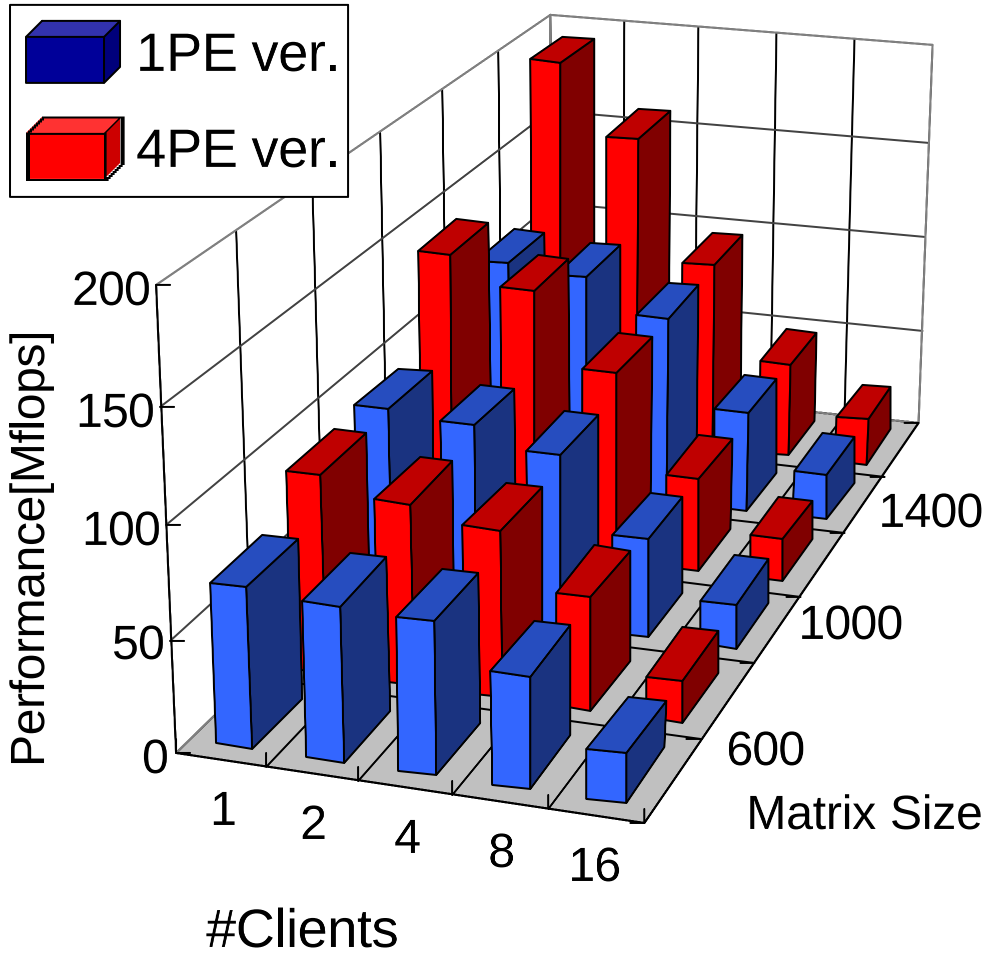
    4PE ver. --- Data Parallel

    4PE Execution and Single Processing
  - **EP**: **1PE ver.** --- Task Parallel

LAN Multi-client Benchmarking Environment (at ETL)

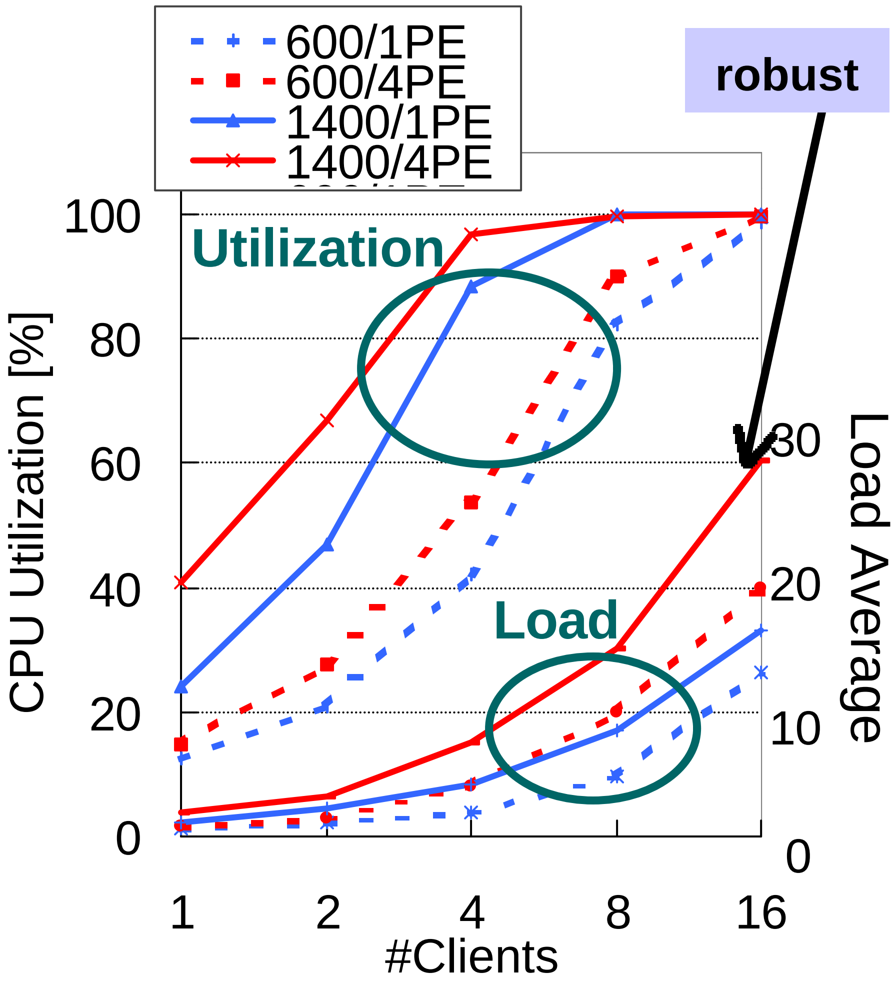


LAN Linpack Benchmark Results
Average Performance



- 4PE ver. exhibits higher performance for a small c,
- while there is little performance edge for the 1PE ver. for a larger c.
  - Numerical core speed
  - Small overhead of switching parallel tasks on J90
  - Overlapped communication
- Average response and waiting time didn't differ depending on n, c, or 1PE / 4PE ver.

LAN Linpack Benchmark Results
CPU Utilization and Load Average



- 4PE ver. exhibits higher Utilization and Load.

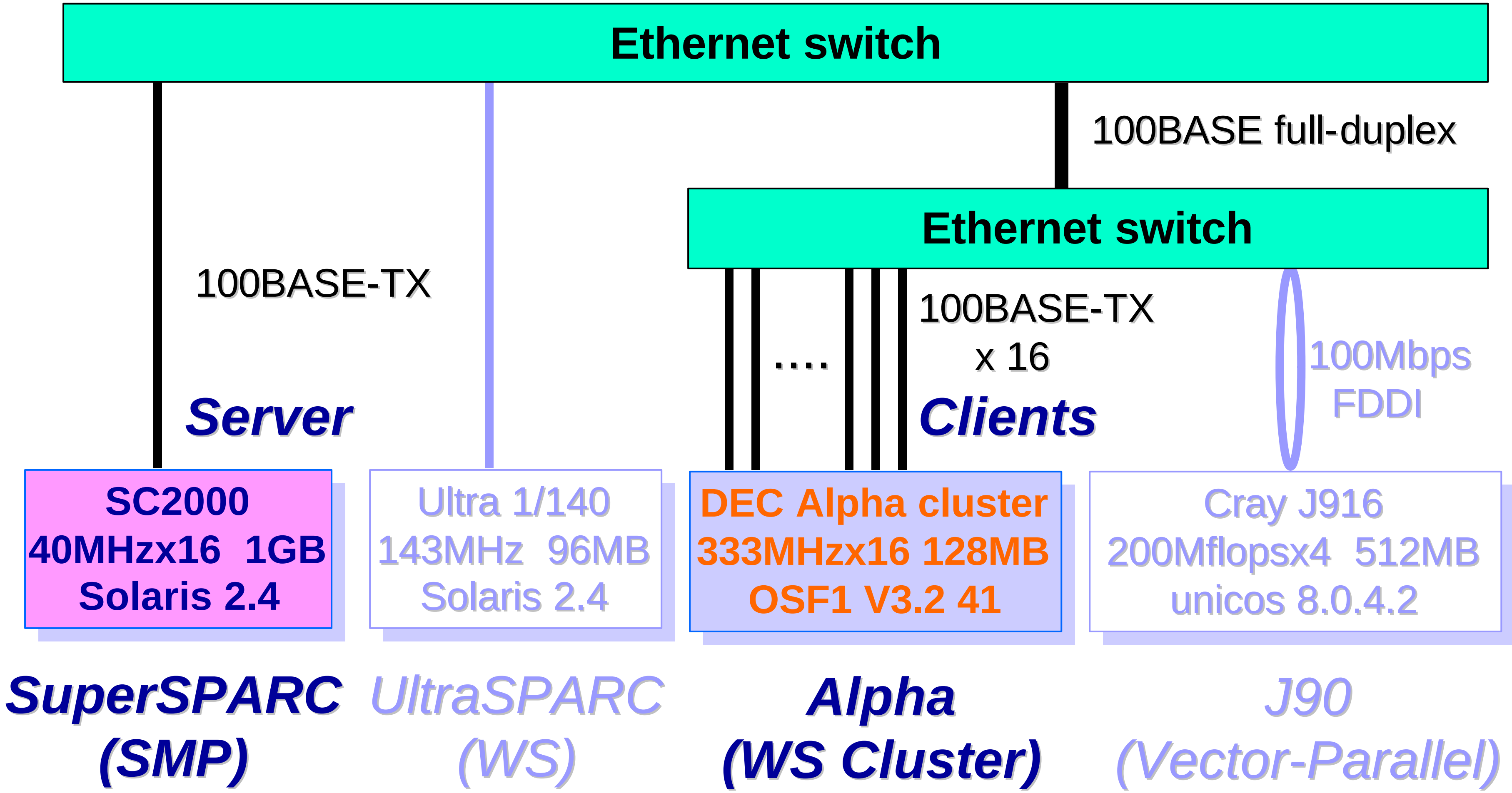
→ The optimized parallel library would be appropriate for J90.

- Utilization and Load are higher as n and c increase.
- The J90 Ninf server continued to work flawlessly.

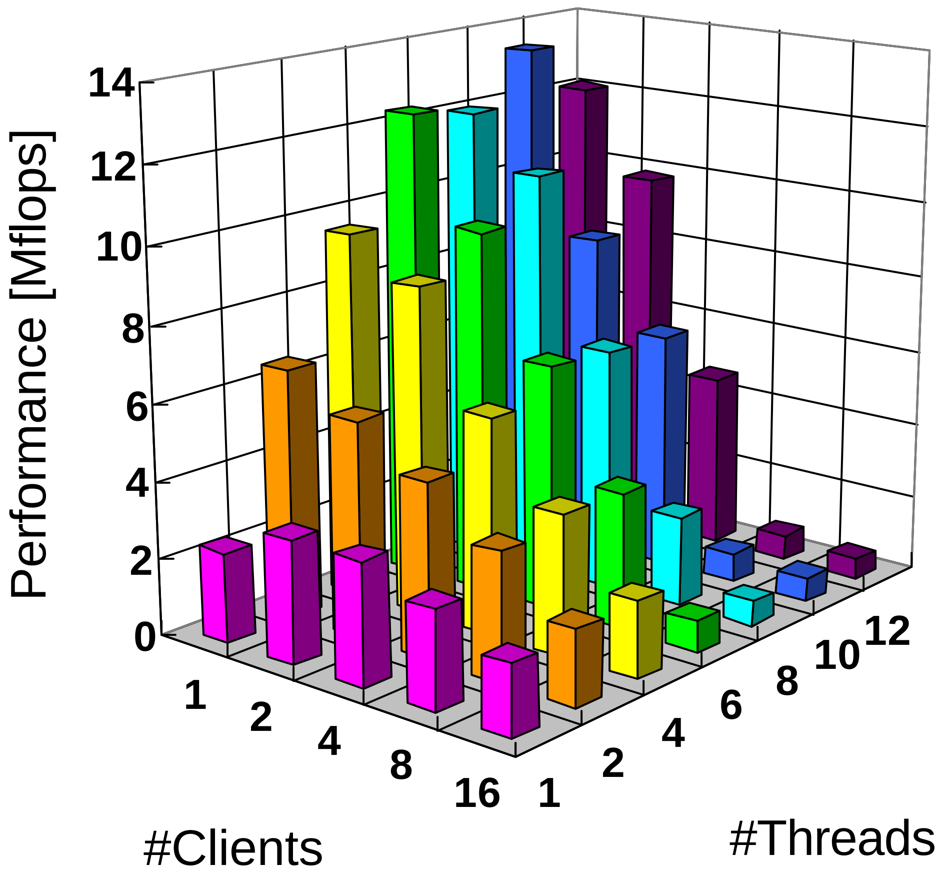
(even for n=1400, 4PE ver.,

max. load average : 30)

LAN SMP Multi-client Benchmarking Environment (at ETL)



Average Performance of Multi-thread LAN Linpack on SPARC SMP



- Highly multi-threaded ver. exhibit notable slowdown.
  - Solaris on SPARC SMP is optimized for handling the requests.
  - do not co-schedule multiple threads.

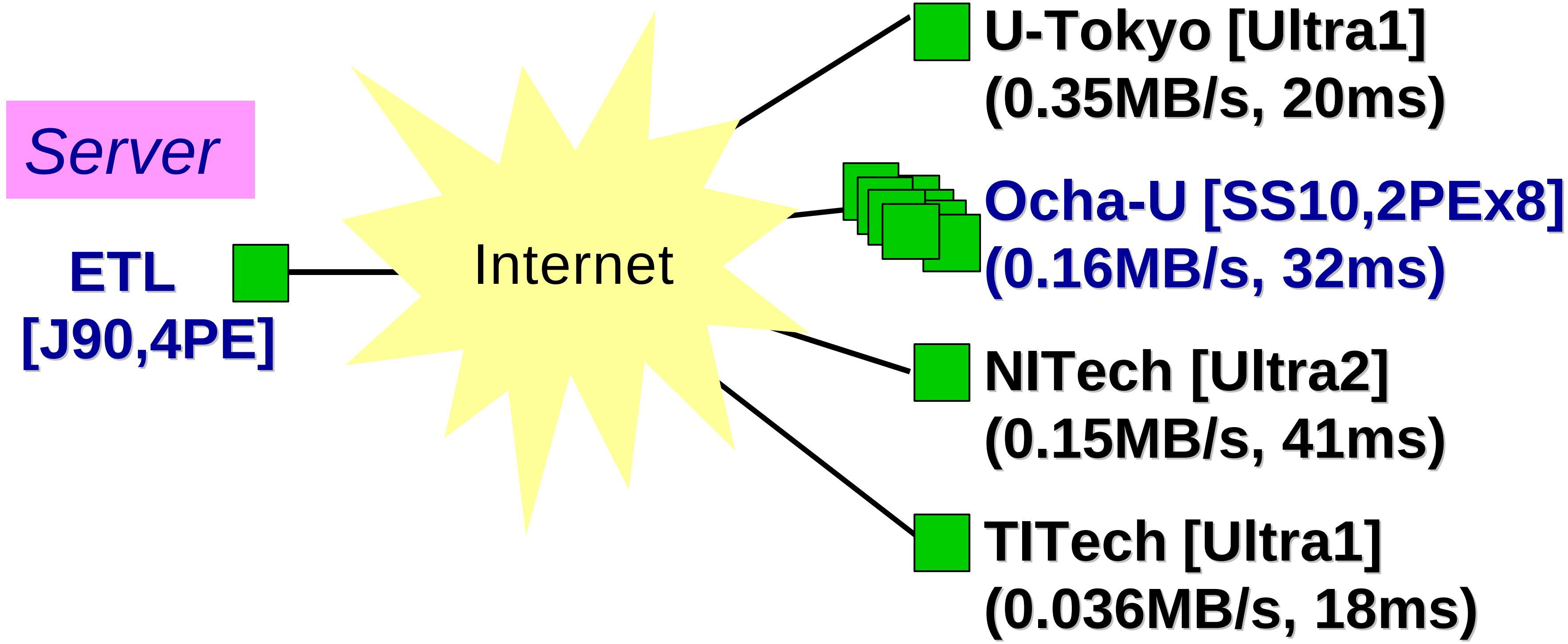
→ thread-switching overhead.

(cache / TLB misses etc.)

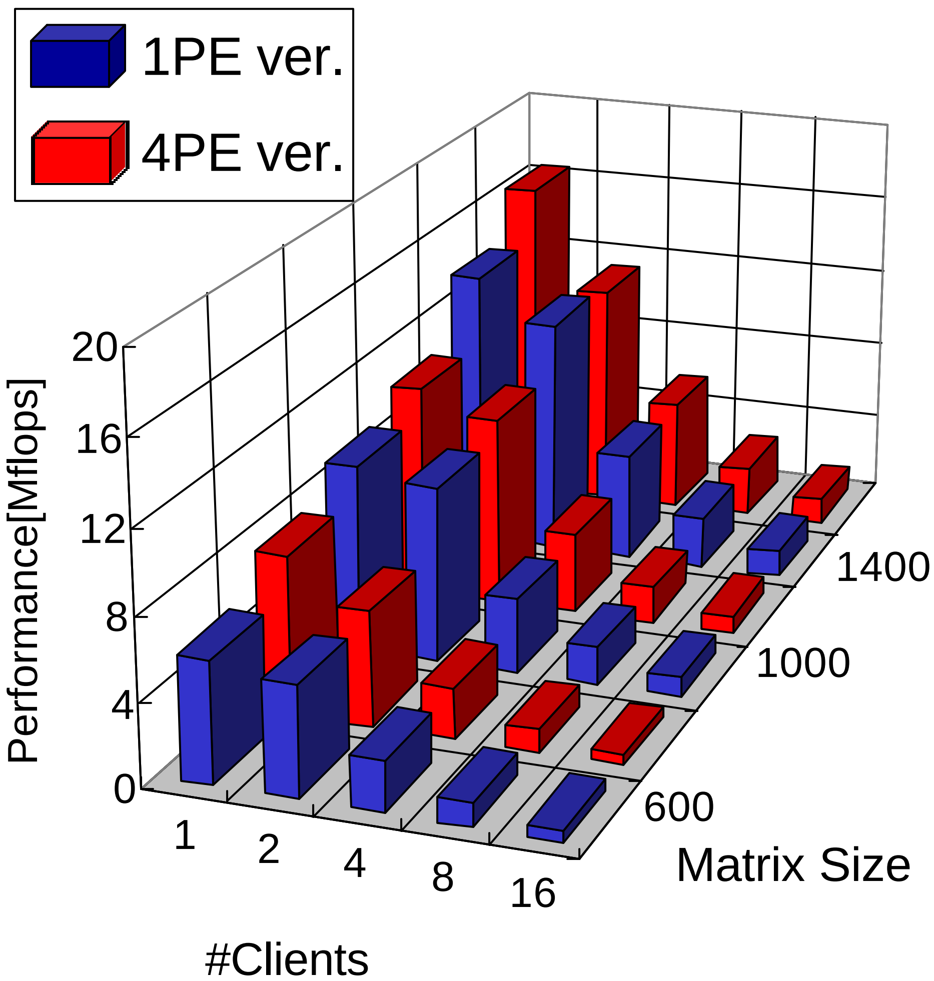
WAN Multi-client Benchmarking Environment

- Single-Site
- Multi-Site

Clients



Single-Site WAN Linpack Benchmark Results
Average Performance



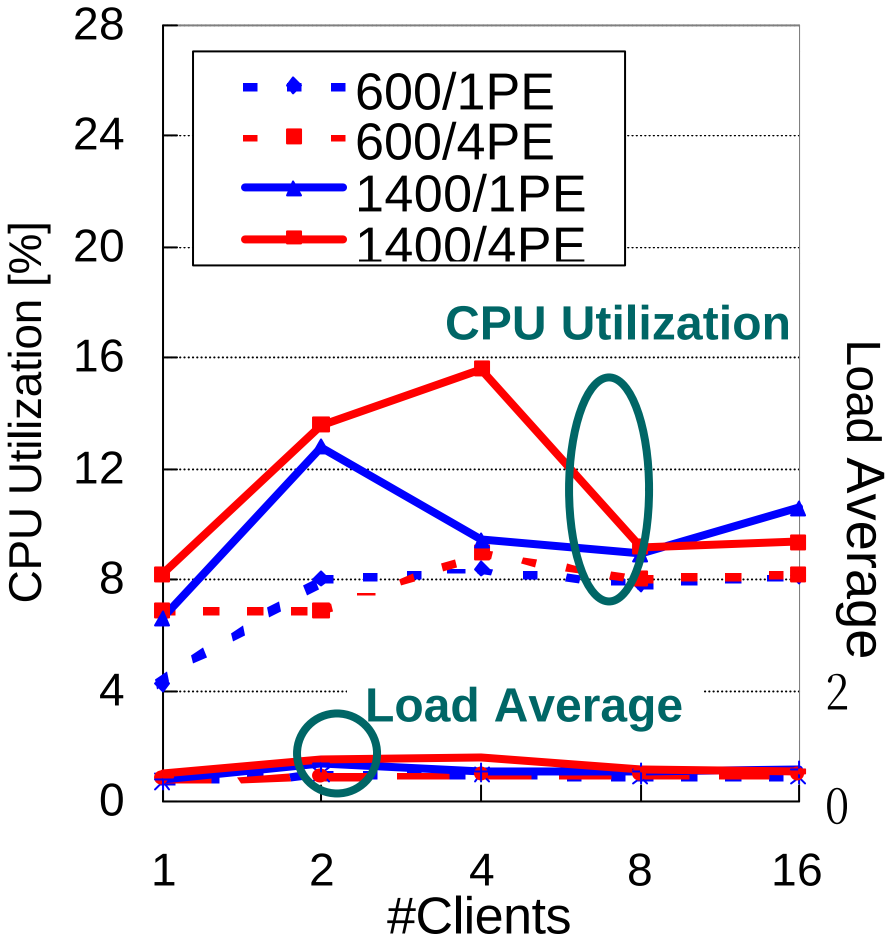
- Ave. performance deteriorates as c increases.

→ The network throughput saturates even for c=1 or 2.

- Exhibited almost the same characteristics as LAN.

→ Better to use the parallel library versions for WAN clients as well for J90.

Single-Site WAN Linpack Benchmark Results
CPU Utilization and Load Average



- Utilization and Load remain low even for c=16.

→ It is difficult for the global computing servers to process numerous requests.

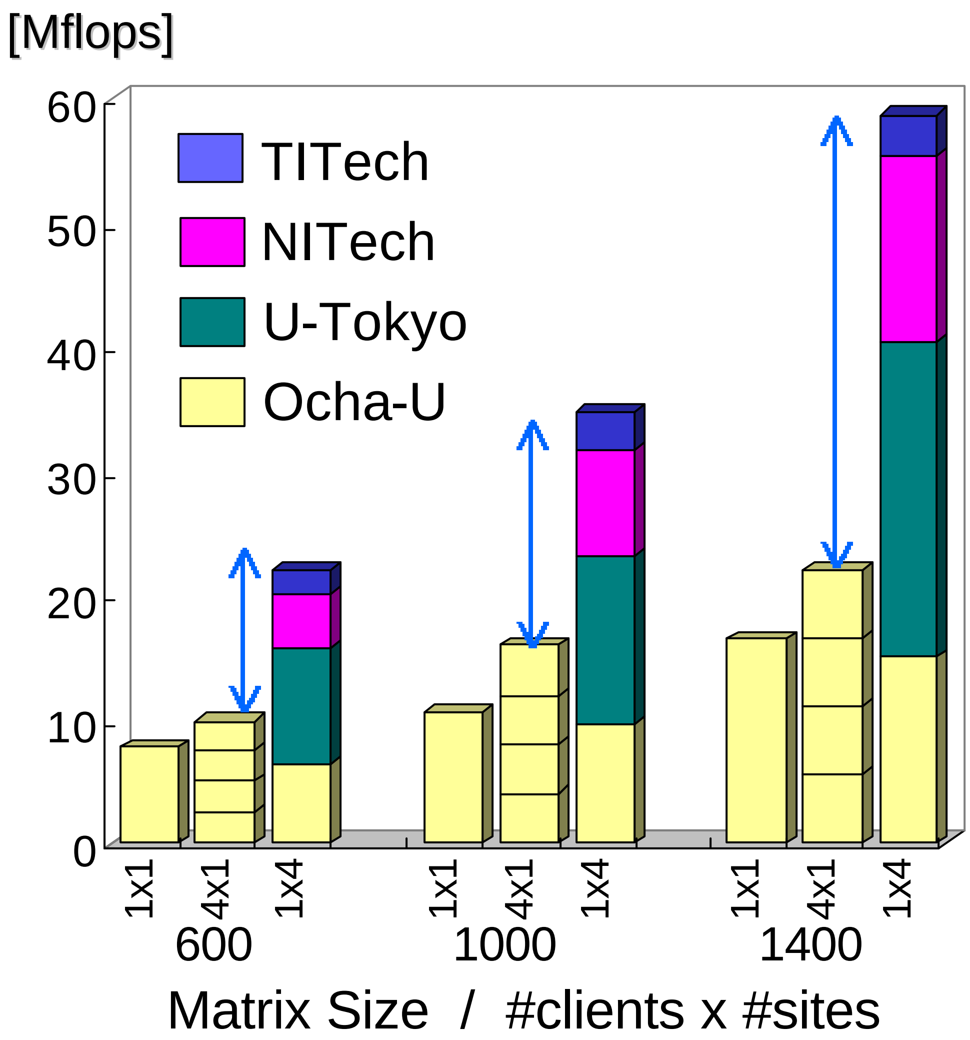
(for communication intensive tasks)

→ A good load balancing algorithm is needed

- server load
- network traffic and topology
- client location etc.

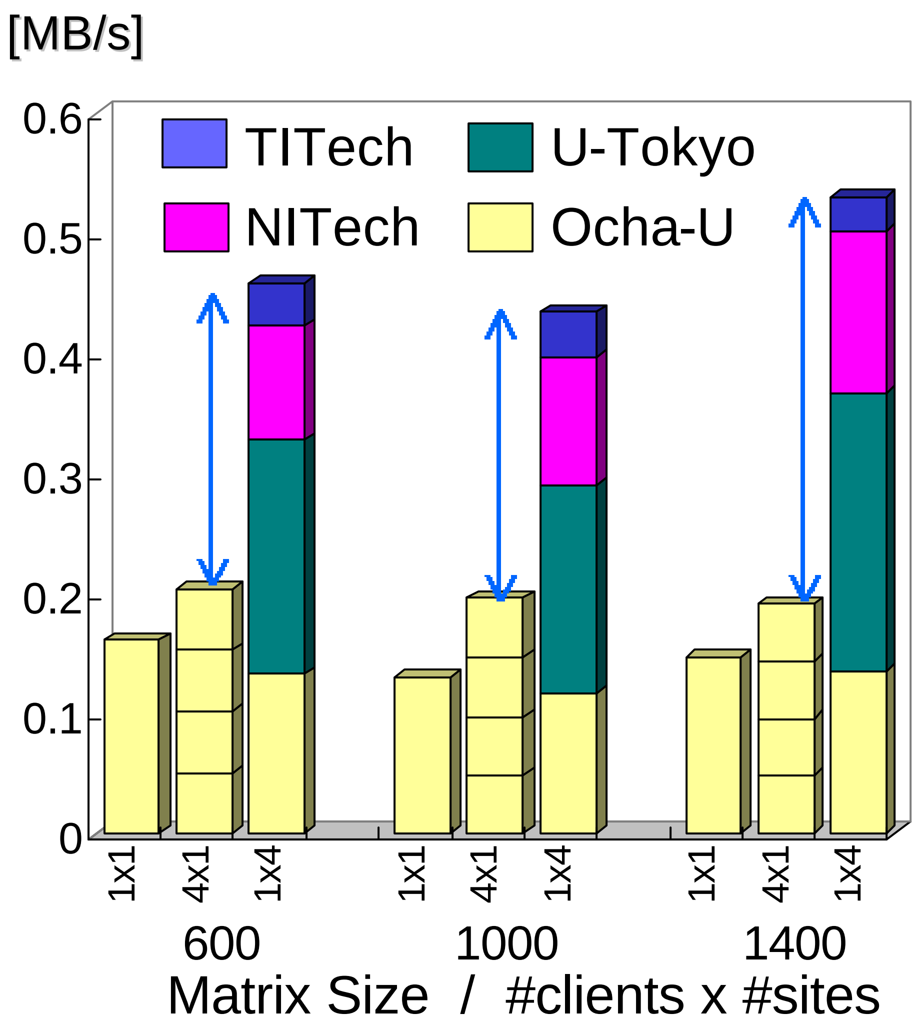
Single/Multi-site WAN Linpack Benchmark Results

Average Performance (c = 4, 4PE ver.)



- Total performance is higher as n increases.
- Aggregate performance from multi-site is substantially higher than from single-site for the same c.

Single/Multi-site WAN Linpack Benchmark Results
Communication Throughput (c = 4, 4PE ver.)

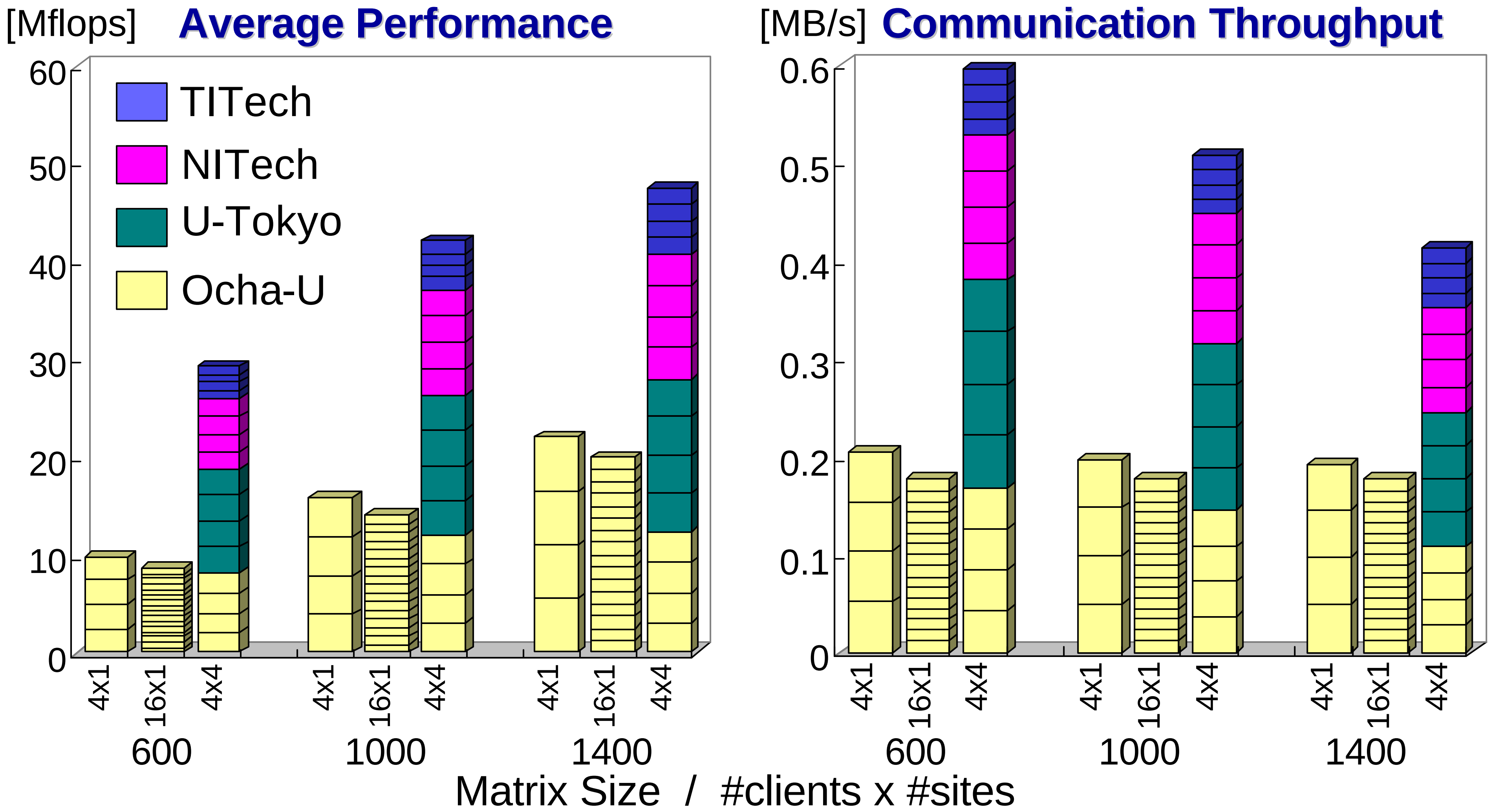


- Total communication throughput is nearly constant for each n.
- Aggregate communication throughput from multi-site is substantially higher than from single-site.

→ **For communication intensive tasks, *point-to-point bandwidth* is the dominant factor in performance. (not latency)**

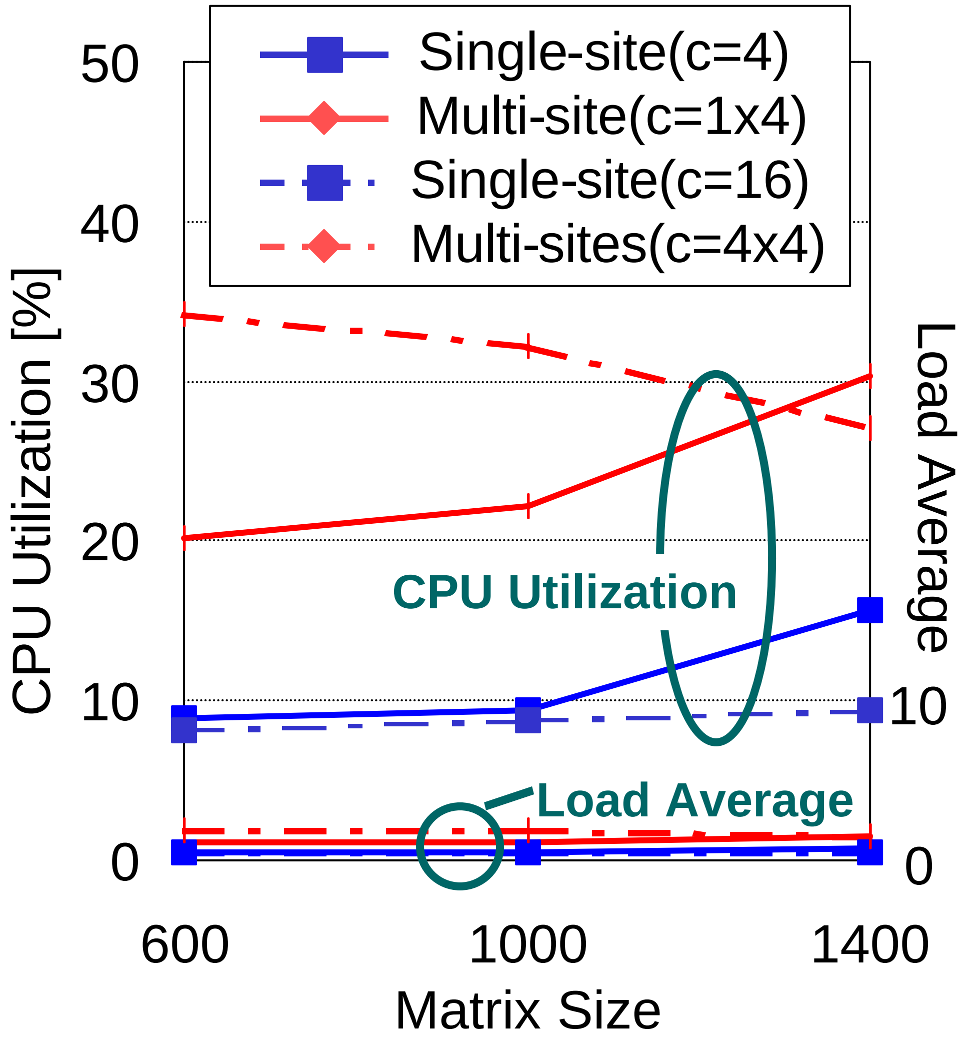
Single/Multi-site WAN Linpack Benchmark Results

Performance and Throughput (c = 16, 4PE ver.)



Single/Multi-site WAN Linpack Benchmark Results

CPU Utilization and Load Average

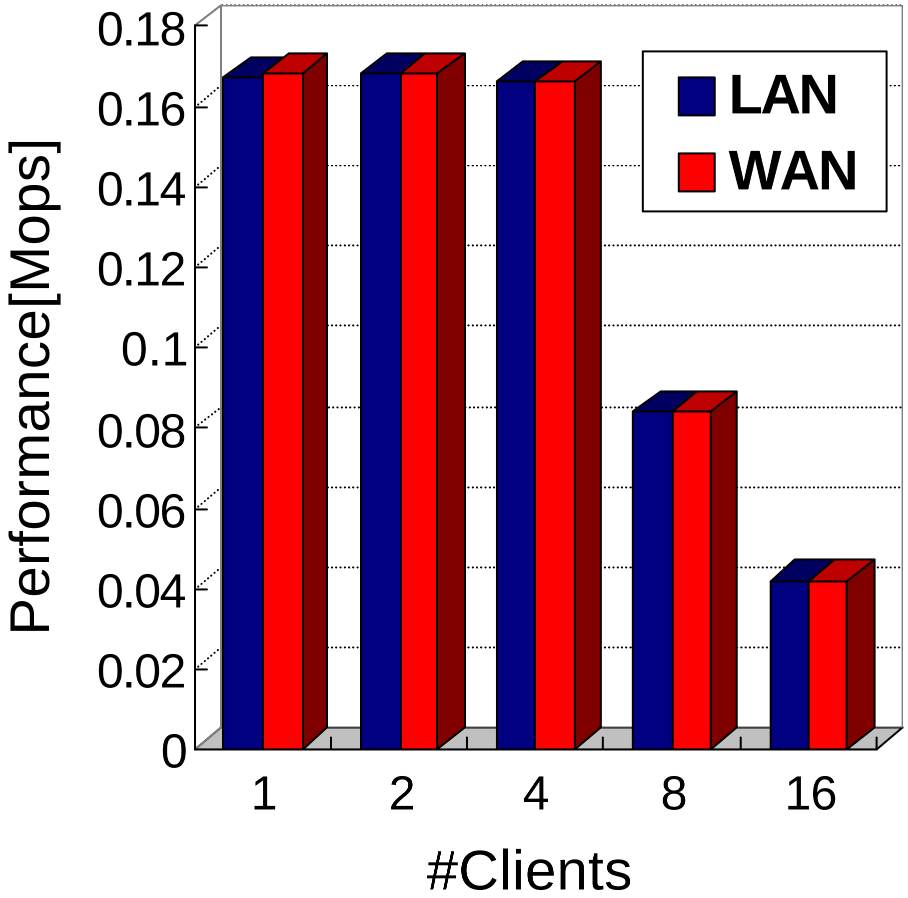


- Utilization and Load are greater for multi-site.

  c.f., single site.
- The J90 server does not saturate for n and c.
  - ***Network bandwidth saturation*** again the cause.

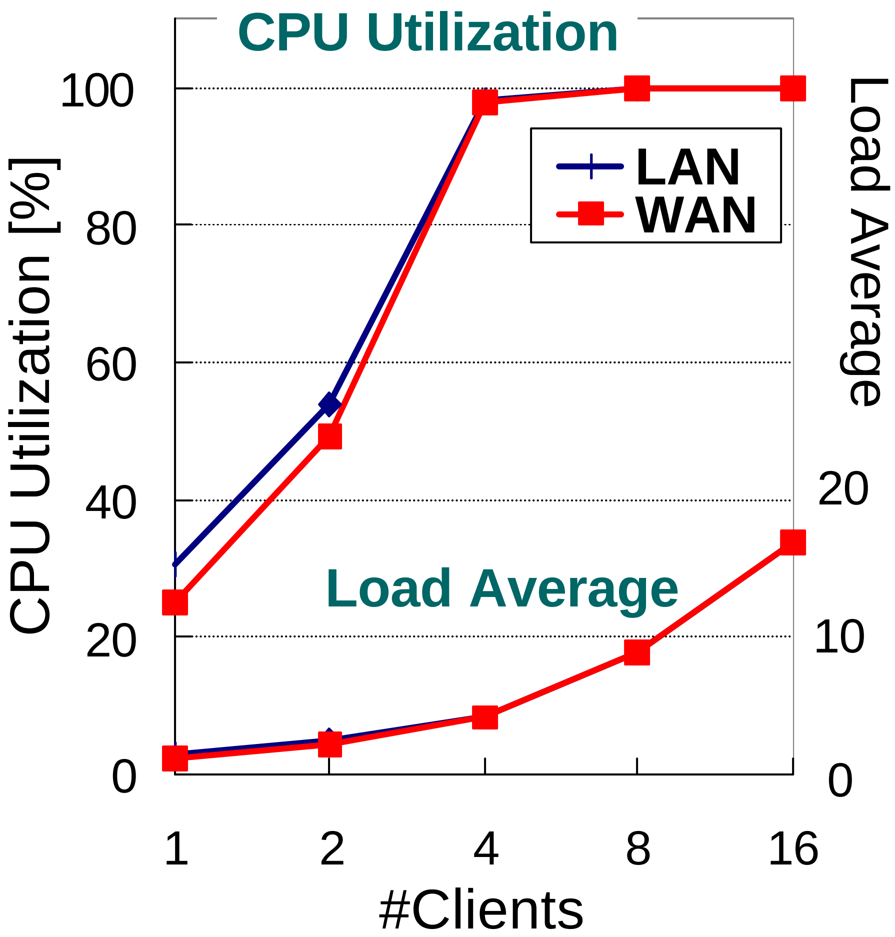
→ **Utilization and Load alone are NOT suitable criteria for load balancing of global computing.**

LAN/WAN EP Benchmark Results Average Performance (1PE ver.)



- Because of task-parallel execution, the performances decline when c=8, 16.
- In both LAN and WAN cases Ninf_call performances are almost equivalent.

LAN/WAN EP Benchmark Results
CPU Utilization and Load Average



- Both LAN and WAN cases are almost equivalent for Utilization and Load.

→ **Global computing can now be considered quite feasible** for this class of applications:

  – parallel rendering / imaging

  – parameter sensitivity analysis

Related Work

- RPC based systems → **use existing programming languages**
  - **NetSolve** [Casanova and Dongarra, Univ. Tennessee]
    - The same basic API as Ninf_call (**now interchangeable**)
    - load-balancing with a daemon process called **Agent**.
  - **RCS** [Arbenz, ETH Zurich]
    - PVM-based
- Systems using parallel distributed language etc.
  - **Legion** [Grimshaw, Univ. Virginia]
    - An user distributes his programs written with the parallel object-oriented language **Mentat**.
  - **Javelin** [Schauser et al., UCSB]
    - High portability due to using **Java** and **WWW**.
- Global scheduling systems - **NWS, AppLeS, DQS**

Conclusion

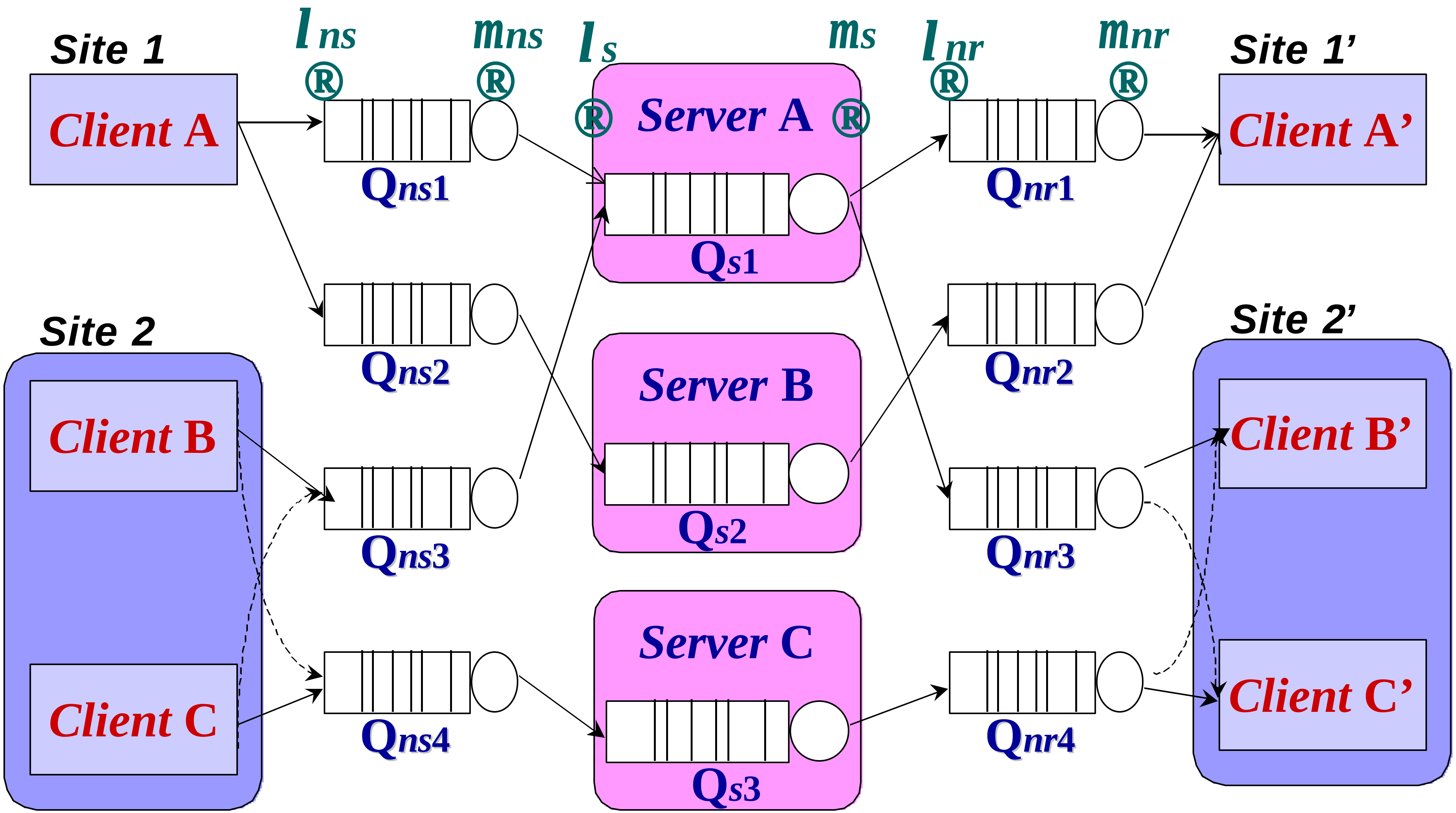
- The current Global Computing systems are likely to work well in both LAN and WAN situations.
- The use of optimized parallel library would be sufficient for vector computing servers.
- In LAN, computing server performance dictates overall performance, while in WAN limitation of communication throughput is more significant. (Esp. communication-intensive applications)
- We expect multiple client requests will be issued from different sites, causing “false” lowering of load ave..

The scheme which properly dispatches communication-/computation-intensive jobs to the servers is important.

Future Work

- Load Balancing for the Global Computing
  - Meta Server (*c.f.* NWS)
  - Develop a theoretical model
    - Performance analysis for more practical situations
    - **Global Computing Simulator**
- Make the Ninf system more powerful
  - Guaranteeing Performance in multi-client global computing
  - Server Job-handling Methodology (FCFS → SJF)
  - Multi-Job Scheduling for MPP servers (FPFS, FPMPFS)
  - Extension of the API for MPP's network services

The Model of Ninf Simulator



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Exhibition

Electro-
technical
Laboratory

Zone R2