携帯機器を用いた高密度ネットワークによる並列分散処理

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近年，携帯電話は年齢を問わず幅広く人々に利用されるようになった．これら大多数の携帯電話で高密度なネットワークを構築し，その上で並列処理に応用できれば，膨大な計算能力を得られるだろう．そこで私たちは携帯電話をはじめ，たくさんの携帯端末を用いたグリッドコンピューティングに関する研究を始めた．本稿では，携帯電話を用いた分散処理環境の基本設計を示す．そして携帯電話を並列分散処理に使う上での問題点を挙げ，それらの解決法を提案する．また，無線 LAN 搭載の携帯電話を用いてベンチマークプログラムを実行して，今後のシミュレーション環境構築のための基礎データ収集を行った．最後に今後の研究方針について示した．

Toward Parallel and Distributed Processing on High-Density Network with Mobile Devices

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Recently, cellular phones have been widely utilized among many people that irrespective of age. If these enormous number of cellular phones are used for parallel processing with high-density network, we would get great processing power. So, we have started research on Grid computing with cellular phones and many other mobile devices. In this paper, we describe the design of parallel and distributed processing. And, we have investigated problems in using of cellular phones for parallel and distributed processing, and propose the solution for them. Moreover, benchmark program of parallel processing is executed with current cellular phones with wireless LAN interface, and measured basic data for the future simulation environment. Finally, we have shown that future works of our research.

1. Introduction

Recently, cellular phones have been widely utilized among many people that irrespective of age. Over 100 millions of cellular phone terminals are used in Japan. We use a cellular phone not merely for verbal communication but also for internet connection, E-mail, data communications, camera, television, JAVA application, music playing, GPS and many other various multimedia services. Though performance of CPU in a cellular phone is still lower than CPUs in desktop PCs or server machines, higher performance is going to be needed for future high level services.

We focus on cellular phones as resources of Grid computing. If these free resources configure network for parallel processing, we would get significantly large computing power. Therefore, a new computing infrastructure is going to be configured with interconnecting and integrating network of cellular phones into network of Grid computing in which a number of PCs and workstations are connected. This base network is named "SILK Network". SILK Network is named from silk fabrics.

In this paper, we present usability of Grid computing with cellular phones with investigating problems on the system and propose solutions for them.

The rest of this paper is organized as follows: related researches are mentioned in section 2. Section 3 describes SILK Network design. Problems on parallel and distributed processing with a number of cellular phones and solutions for them are shown in section 4. Section 5 measured basic data for the SILK Network simulation. Finally we describe future works in section 6, and conclude in section 7.

2. Related Works

There are several researches with using mobile devices into the Grid computing. Phan et al. have intro-

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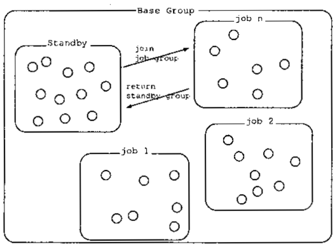

図 1 SILK Network でのジョブ管理
Fig. 1 Job management of SILK Network

duced a proxy-based cluster architecture with applying mobile devices into traditional Grid network[1]. Clarke and Humphrey have investigated challenges with coupling mobile devices into the Legion Grid computing system[2].

David and Matry have proposed Mobile OGSI.NET[3]. OGSI (Open Grid Services Infrastructure) is provided with Globus ToolKit which is the most standard middleware of Grid computing. They have mounted it with .NET Compact Framework of the Windows CE.

These researches do not target upon cellular phones but lap-top PCs or PDAs for Grid computing.

However, we focus on possibility to realize mobile Grid computing with a number of cellular phones and all mobile devices.

3. Design of SILK Network

When we use cellular phones for Grid computing, the network connectivity is unstable, because cellular phones communicate via wireless communication. Therefore, we create the destributed processing environment over P2P(peer-to-peer) network, because P2P network needs no server so peer's disconnection has little influence on the entire network. One of the P2P library is JXTA[4]. This library is an open source P2P library introduced by Sun Microsystems. We use JXTA for SILK Network.

Job management of SILK Network is shown in Figure 1. At first, a cellular phone that connects to network joins Standby Group in Base Group. And it waits to be given a job or issues a job. When a cellular phone issues a job, it creates a new job group. And it sends broadcast message to Standby Group to announce a new job group. When a cellular phone joins a job group that other one created, it executes a given process.

And then, we implement MPI, RPC, or other parallel processing library over the network to execute the distributed processing.

表 1 W-ZERO3 および評価に使用した PC の性能
Table 1 Specification of W-ZERO3 and currently utilized PC

	W-ZERO3	PC
CPU	PXA270 416MHz	Pentium4 HT 3.0GHz
OS	Win Mobile 5.0 for PPC	WinXP Pro SP2
Memory	SDRAM 64MB	DDR2-SDRAM 1GB

表 2 Linpack Benchmark の実行結果
Table 2 Results of Linpack Benchmark

	single precision	double precision
W-ZERO3	2.12Mflops	1.17Mflops
PC	547Mflops	560Mflops

4. Problems in Parallel Processing with Cellular Phones

In this section, we describe problems in using cellular phones for parallel and distributed processing.

4.1 Floating Point Processing with Cellular Phones

As mentioned before, cellular phones are equipping with embedded processor, and many application programs such as multimedia services have been widely executed in them. However, most processors are not equipped with a high-performance arithmetic unit such as FPU (floating point processing unit).

First of all, we have evaluated floating-point arithmetic computation with a single cellular phone. W-ZERO3 (WS004SH) manufactured by SHARP which is one of the highest performance cellular phones is used for the evaluation. Linpack Benchmarkadopted for Top500is used for the benchmark program. Table 1 shows comparison between W-ZERO3 and an ordinary PC. Since an FPU is not equipped in W-ZERO3, a Linpack Benchmark program is executed with soft-float.

A result of performance evaluation with the floating-point arithmetic by Linpack Benchmark is shown in Table 2.

As for single-precision floating-point arithmetic, there is a performance difference of about 260 times between cellular phone and an ordinary PC.

As for the performance of double-precision, cellular phone is as 480 times slow as the PC. The difference of CPU clock is about seven times. From the result, it spends a long time with a cellular phone in floating-point arithmetic computation.

Therefore, computational performance in a cellular phone has been expected for higher performance in parallel processing.

4.2 Life of Battery of Cellular Phones

When Grid computing would be realized with a number of cellular phones, processing for Grid computing are executed in each cellular phone which is not used by each owner. The problem is that battery has been consumed for the processing. While it is free, a cellular phone usually prevent electric power consumption as much as possible.

While a cellular phone keeps on executing application, the battery is run out in about two hours. Coexistence of Grid computing with a cellular phone and utilizing by the owner is still difficult with such a short life time of battery. Therefore, capacity, lifetime or even new mechanism for a battery will be indispensable for future Mobile Grid Computing.

4.3 Network Interface of Cellular Phones

Though cellular phone can connect to Internet to see Web sites, data transfer system of a cellular phone has peculiar interface, thus most cellular phones cannot directly connect with PCs via LAN.

Though there are some terminal devices which are equipped with interface of wireless LAN or Bluetooth, these are limited to few models of high-performance cellular phones. Therefore, wireless LAN interface should be equipped into an ordinary widely used cellular phones.

4.4 Overcoming These Problems

To overcome these problems, we propose a external device which is connected to a cellular phone. The external device mounts the arithmetic unit such as a CPU and an FPU with helping the cellular phone to execute heavy applications or other floating computations.

In addition, since it is installed with battery charging facility, it can charge the cellular phone. We named the external device as "SILK Box".

In the future, we expect functions of SILK Box would be shipped into a cellular phone by improvement of battery technology and semiconductor device technology.

We make experimetal environment. This environment supports floating computations for a cellular phone to execute floating-point arithmetic. A processor is implemented in an FPGA, and a floating computation is executed by the processor. At the present, though we use MicroBlaze manufactured by XILINX as a SILK Box processor, we are going to utilize higher performance processor such as an SMT[5)6)7)] at later stage.

5. Effectivity of Mobile Parallel Processing

As shown in the above, since there exists various problems in parallel and distributed processing with using cellular phones, few researches has been done since ever. However, it is possible to gain higher performance with parallel processing using existing multiple cellular phones.

表 3 行列乗算での性能向上率

Table 3 Speed up ratio of matrix multiplication

Number of mobiles	Execution time(s)	Speed up ratio
1	8.356	-
2	6.642	1.25

表 4 2 億加算での性能向上率

Table 4 Speed up ratio of 200 million addition

Number of mobiles	Execution time(s)	Speed up ratio
1	4.458	-
2	2.404	1.85

We are creating a SILK Network simulator to show possibility and feasibility of mobile parallel processing. In this section, benchmark programs of parallel processing are executed with current cellular phones, and we measured performance for the simulation environment.

5.1 Evaluation Environment

We utilize two set of W-ZERO3 (WS004SH) manufactured by SHARP for the evaluation. Table 1 shows the specifications of W-ZERO3. These terminal devices are connected via wireless LAN and each communicates with speed of 11 Mbps.

A matrix multiplication (256 $\times$ 256) program and a 200 million addition program are used as evaluation programs. As a compiler "Microsoft eMbedded Visual C++ 4.0" is used. Benchmark programs are parallelized by hands. Terminal devices send and receive data with each other by using "winsock2.lib" and wireless LAN interface.

5.2 Evaluation Results

We compare the execution time for each benchmark with a single device and two devices. The execution time and speed up ratio of each benchmark are shown in table 3 and table 4 respectively.

Performance improvement of matrix multiplication shows only 1.25 times faster, because it takes a long time to transfer the line of 256 $\times$ 256 and to establish connection of TCP/IP.

However, performance improvement of 200 million addition is 1.85 times faster, because there is less data transmission time comparing with matrix multiplication.

We have measured the time of overhead to connect and disconnect in TCP/IP. The time is about 0.2 seconds in this evaluation environment.

The transfer time for one set of 256 $\times$ 256 matrix is about 0.2 seconds, because we use wireless LAN of IEEE802.11b standard (11Mbps). Since the program transfers 3 sets of the matrix, it is clear that the data transfer time in the benchmark spends over 0.6 seconds.

As the result shows, performance improvement of matrix multiplication and 200 million addition is theoretically valid.

In this experiments, we have evaluated the performance with two terminal devices in order to compare with the theoretical values. The measured data is going to be utilized as a basic data to evaluate a parallel processing system with an enormous number of cellular phones by simulation in the future.

6. Future works

We are going to describe about what to do in the future as follows.

6.1 Improving SILK Box

Though MicroBlaze equipped in a current SILK Box as a processor has an FPU unit in it, the performance is not so high. Thus it is needed to implement higher performance CPU with a small amount of hardware. Moreover, environment to supplement functions which are necessary in SILK Box in order to implement middleware and parallel processing libraries.

6.2 Middleware

In order to configure Grid Computing environment with cellular phones, mechanisms for resource management and job assignment are needed, thus implementation of Grid middleware such as Globus ToolKit available in cellular phones is indispensable.

6.3 Parallel Processing Library

In the evaluation, thought parallelization of benchmark programs has been done by hands, programming with parallel processing library such as MPI makes it possible to program with a significant number of terminal devices. Parallel processing libraries are going to be implemented in our experiment environment.

6.4 Simulator of Parallel and Distributed Processing Environment

Before implementing a parallel and distributed processing system with a large number of cellular phones, evaluation by simulation is needed. Therefore, we are going to conduct a simulation environment in order to evaluate a large parallel and distributed system with virtually using a large number of cellular phones. I would spend much time for simulation by software, thus we are now designing a simulation system with using multiple FPGAs in order to simulate by hardware in a shorter time than software.

7. Conclusion

In this paper, we describe the possibility of parallel and distributed processing with cellular phones. Cellular phones have been widely used among people all over the world that irrespective of age. If these free resources configure network for parallel processing, we would get significantly large computing power.

Therefore, we have investigated problems in using of cellular phones for parallel and distributed processing, and propose the solution for them. And, we propose a external device (SILK Box) which is connected to a cellular phone.

Next, benchmark program of parallel processing is executed with current cellular phones with wireless LAN interface, and measured performance for the future simulation environment.

Finally, we have shown that future works of our research.

Acknowledgments

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