Performance Evaluation of the LSC by Simulations of a Cascade Shower Model

Xinchun Zhao Akiko Narita Satoshi Mituta

Yoshioka Yoshio

24 May 1999

Corresponding Author: Xinchun Zhao Research Student at Department of Information Science,Hirosaki University, Japan.

Postal address: International House,Room:A204

2-20-17 Kikyono,Hirosaki,Aomori Ken,Japan. 036-8227

Phone: 0172-350431

Fax: 0172-393626

Email: si97009@si.hirosaki-u.ac.jp

Akiko Narita Associate Professor at Department of Information Science, Hirosaki University,Japan

3 Bunkyoucho,Hirosaki, Aomori Ken, Japan. 036-8560

Satoshi Mituta Associate Professor at Department of Information Science, Hirosaki University, Japan.

3 Bunkyoucho,Hirosaki, Aomori Ken, Japan. 036-8560

Yoshioka Yoshio Professor at Department of Information Science, Hirosaki University,Japan.

3 Bunkyoucho,Hirosaki, Aomori Ken, Japan. 036-8560

Abstract

We perform the simulations of cascade shower on a parallel computer called LSC(Loop Structured Computer) with 128 PEs. The 128 PEs are connected to make a loop configuration. It is easy to distribute packets among the PEs connected in the same direction. In the simulations, we measure the execution time, the number of PEs used and the number of particles produced on the LSC with different number of PEs. We also investigate the relation between the execution time and the number of particles produced on 1 computation PE LSC. Then according to this relation, we calculate the extrapolated execution time on 1 computation PE LSC for the simulation with high primary energy. Using this extrapolated execution time and actual execution time on 128-PE LSC, we calculate the speedup and efficiency of the LSC. On the other hand, we measure the highest primary energy (HEP) *of executable simulation. By changing the number of PEs of the LSC, we obtain the* HEP*s of the LSC with different number of PEs. According to these* HEP*s, we obtain an approximated equation calculating capability of the LSC for processing data. Finally, we analyze the speedup and efficiency of the LSC.*

Keywords: *cascade shower simulation, performance evaluation, speedup, efficiency, LSC, Loop Structured Computer.*

1 The LSC

1.1 Architecture

The architecture of the LSC is shown in Figure 1. These 128 PEs are connected to make a loop configuration. The data is transferred among the *shifter register* of each PE along same direction. The communication PE(PE_0) is responsible for the communication between the LSC and the host computer. The communication PE is connected to the host computer by RS-232C. The other 127 PEs (PE_1 to PE_{127}) are computation PEs which are used to process data. The number of computation

PEs can be changed(numbered from 1 to 127). Each computation PE is constructed with a MC68B09 MPU with a small amount (7224bytes) of local memory. The host computer is Fujitsu FMV-590Tsp with 133MHz CPU. The data is packaged into packet (24 bytes long) and then transferred to its associated PE. The features of the LSC are described as follows:

- All PEs are connected to make a loop configuration.
- PEs may communicate with each other by transferring packet along same direction.
- The operations of the LSC are controlled by the instruction from the host computer.
- The number of computation PEs is variable(numbered from 1 to 127)
- Each individual PE can operate a separate instruction.
- Each PE can operate independently on its own data stream.

1.2 Packet Format

Whether between the host computer and the PEs or among the PEs, the instructions as well as the data, is transferred in packet. A packet is 24 bytes long. The packet format is given in Figure 2. Figure 2 shows that a packet contains *the function code, the destination PE number, the source PE number, the counter, the history, the data field 1 and 2.*

PE1— PE127: Computation PE

PE0 : Communication PE

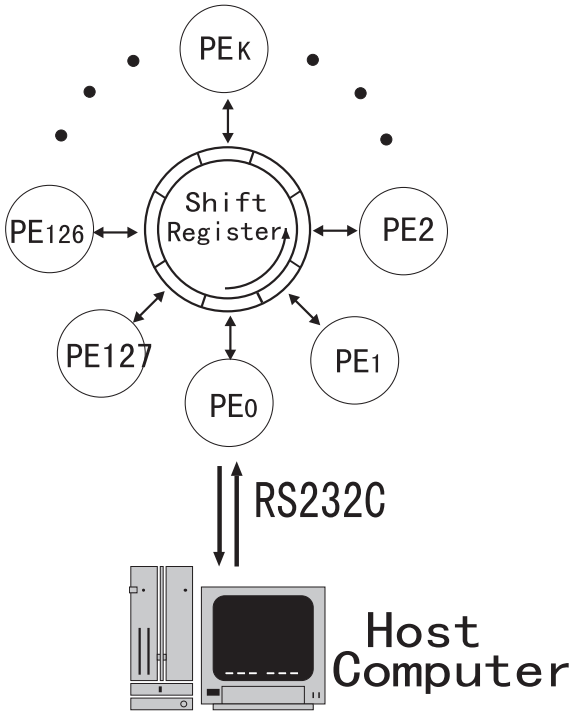

FIGURE 1 The Architecture of the LSC

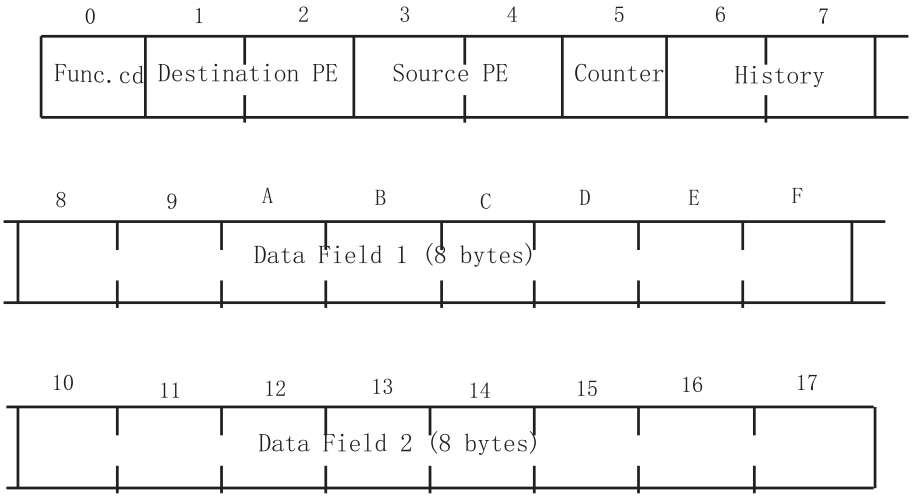

FIGURE 2 The Packet Format

1.3 Data Packet Distributions

The results generated in any computation PE are packaged into the packets. The packet format has been already described in subsection 2.2. The two produced data(energy and radiation length of a particle,in this simulation) are packaged into the *data field 1* and *data field 2*, the current PE number is packed into the *Destination PE* and *Source PE*, set the value of the *Counter* be 1(*Counter* equals 1 plus the number of rounds where the packet travels around the loop of PEs). The packet is transferred to the shifter register of the next PE. Then the value of *Counter* of this packet is compared to the number of packets stored in the *Packet Buffer* of current PE. If the *Counter* is larger, the packet is read and stored in the *Packet Buffer* of current PE and the *Destination PE* is changed to current PE number. Otherwise, this packet is transferred to the next PE, and the above operations are repeated. By this method the data packets are distributed. If the *Packet Buffers*(capacity of 160 packets) of every PE become full and the value of *Counter will* reach 161, the packet can not be received by any PE and it will be transferred to the communication PE to wait in a queue for the operations of each computation PE.

2 Cascade Shower

2.1 The Cascade Shower

One of the most impressive results of the combined effect of pair production and bremsstrahlung by high energy photons and electrons is the formation of the electron-photon shower. A parent electron will radiate photons, which convert to electron-positron pairs, which radiate and produce additional electron-positron pairs in turn, the number of particles(electrons, positrons and photons) increases exponentially with depth in the medium. The result is a cascade shower of photons, electrons and positrons(see Figure 3)[3]. The energy of produced particles decreases gradually. This process continues until the energy of the produced electron, positron or pho-

ton drops below a critical energy, where we suppose that ionization loss suddenly becomes important and no further radiation is possible. The shower will thus reach a maximum and then stop abruptly.

2.2 The Bremsstrahlung and Pair Production

When a high energy electron in matter passes near a nucleus, the direction of motion of this electron will be varied and a secondary photon will be emitted. This process is called *bremsstrahlung*. In turn, a high energy photon converts into an electron and positron pair by the electromagnetic effect in the electric field of a nucleus. This process is called *pair production*. Usually the photon has a very small energy so that a single electron will produce copious quantities of low energy photons. The energy of later produced particles decreases gradually.

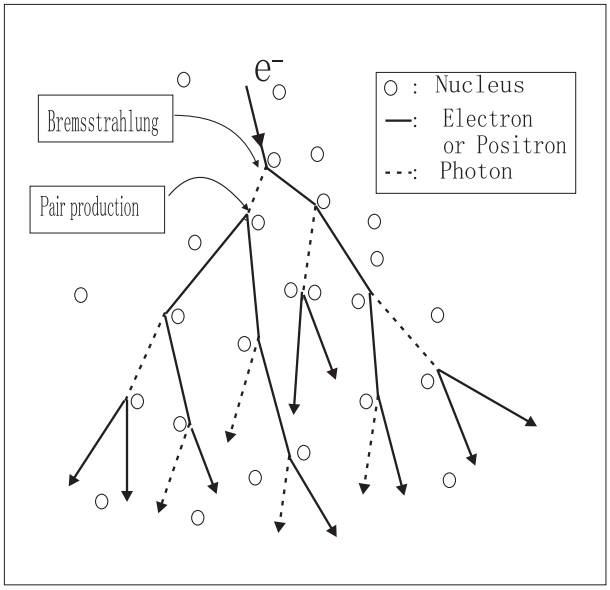

FIGURE 3 The Cascade Shower in Materials

3 Simulations of a Cascade Shower

3.1 Algorithm and program for the simulations

We developed the algorithm and the programs in C language and Assembly for the simulations. The algorithm is shown in Figure 4.

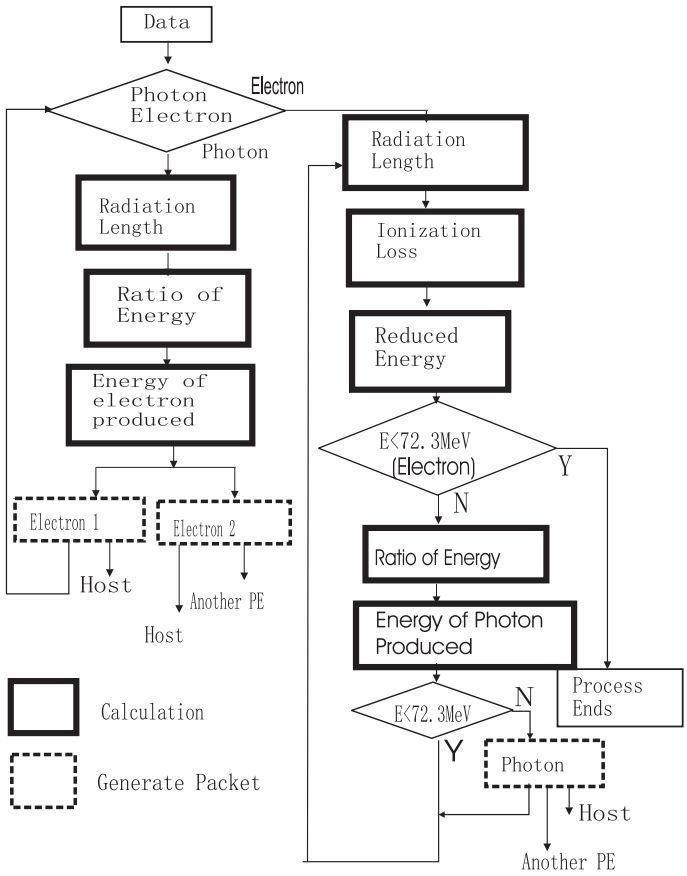

FIGURE 4 The Algorithm of the Simulations

In our simulations, we choose about 50 initial energies and perform the simulations 5 times for the same primary energy. We take the primary energy of 4×10^7, 5×10^7, 6×10^7 ..., 1×10^8, 2×10^8 ..., 1×10^9 ..., 2×10^9. If we change the value of the primary energy, we can obtain the different results.

We also simulated cascade showers on the LSC with 112, 96, 80, 64, 48, 32,16 and 2 PEs. The simulation method is the same as on the LSC with 128 PEs.

3.2 Simulation results

In the simulations on 128-PE LSC, we use about 50 primary energies. After a simulation is over, we obtain the result containing the execution time, the number of PEs used, the number of particles produced, the number of generations, the radiation length and the energy of the produced particles.

4 Analysis of Results

4.1 Speed-up and Efficiency of the LSC

In general, the following two theoretical indices are often used for measuring the performance of a parallel computer: the speedup and the efficiency. The speedup S_p and efficiency E_p are defined as [3]

$$S_p = T_1/T_p, \tag{1}$$

$$E_p = S_p/p \tag{2}$$

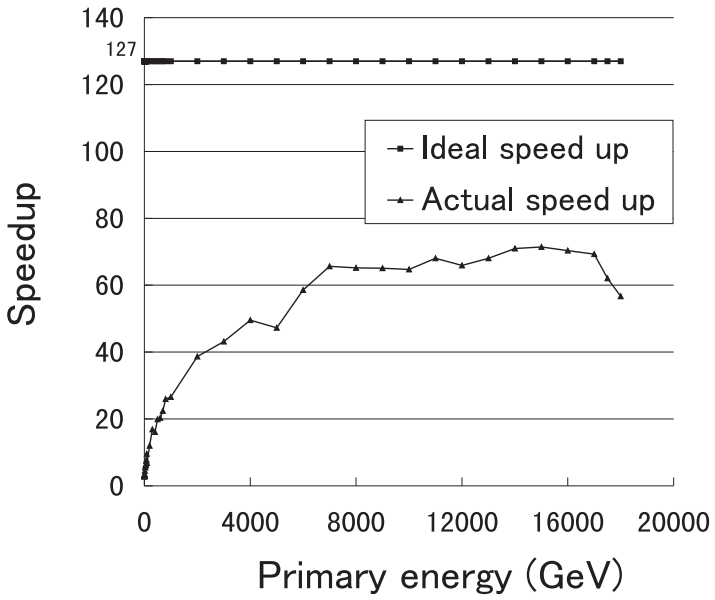

FIGURE 5 The Comparision between the Ideal Speedup and the Actual Speedup

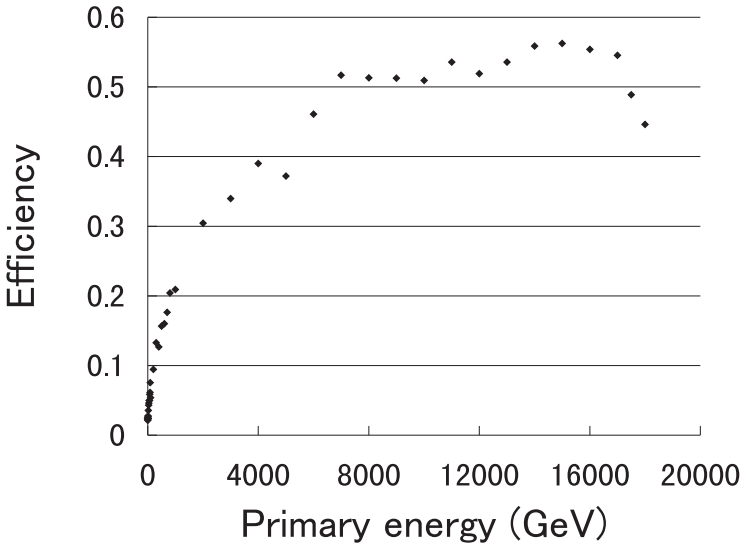

FIGURE 6 The Efficiency of the 128-PE LSC

5 Conclusions

In this paper we have evaluated the performance of parallel processing of the LSC by the cascade shower simulation. We have investigated the capability of the LSC for processing data. Furthermore, We have obtained the speedup and efficiency of the LSC by a most general method. The maximum speedup is round 70 and the maximum efficiency is round 0.55.The speedup and efficiency are low when the simulations are performed by low primary energy. Finally we analyzed the reason why the speedup obtained using lower primary energy to simulate is lower than that by using higher primary energy. In addition, We have investigated the capability of the LSC for processing data.

Acknowledgments

I would like to thank many people who have given me lots of help during my stay abroad in Japan and during my writing of this paper.In particular, my

very special thanks are to Prof. Y. Yoshioka, Dr. S. Mizuta and Dr. S. Narita for their constructive criticism and invaluable guidance. I am also very grateful to Prof. Konisi for his help, guidance and suggestions. I also express my thanks to Mr. Hiramatu whose thesis was very helpful to me. I would also like to thank Mr. Brian Zylstra, my friend, an English teacher at Hirosaki Seiai High School, for his help in checking my thesis for grammatical mistakes.

References

[1] Yoshio Yoshioka. *A Data Flow Parallel Computer LSC(Loop Structured Computer.* Fuji Soft Publisher.

[2] Yoshio Yoshioka. *Parallel Computer.* Hirosaki University.

[3] Hiramatu. *Performance Evaluation of the LSC for Self-production Model.* Hirosaki University,1998.

[4] William R.Lao. *Techniques for Nuclear and Particle Physics Experiments.* Springer- Verlag Berlin Heidelberg,1987.

[5] Pradip K. Srimani and Rachamallu L. N. Reddy. *Another distributed algorithm for multiple entries to a critical section.* Information Processing Letters, 41(1):51-57, 21 January 1992.

[6] Zhengzhong Xu. *Load Balancing in Parallel Computers:Theory and Practice.* Kluwer Academic Publishers, Boston, ISBN 0-7923-9819-X, November 1996.