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PRACTICAL ASPECTS OF USING VIRTUALIZATION WITH RASPBERRY PI CLUSTERS

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ABSTRACT

In this paper we demonstrated the Raspberry Pi cluster consisted of four units. They are interconnected and can be accessed as a singe unit from the outside world. This has been made possible by connecting the cluster to the Internet, and having the working connection to accept the user requests. With the simple use case scenario, we have demonstrated the practical usage of Raspberry Pi cluster.

INTRODUCTION

One of the directions of the development of computer technology is the development of hardware accelerators to support the execution of the proposed algorithms. Thanks to the development of semiconductor technology, these accelerators are increasingly realized as FPGA/ASIC modules. One of the possibilities for realization of hardware accelerators is the use of computer clusters, which allow parallel execution of the program. Computer clusters were additionally gaining importance when they began to be based on cheap microcomputers, realized as modules on a single board.

Particularly significant progress in parallel computing was achieved through computer clusters realized within the TCP/IP network [1], [2]. In such systems, parallel computation is achieved on the principles of message exchange. The best known systems for parallel computing at the level of TCP/IP clusters are MPI (Message Passing Interface), [3], [4] and PVM (Parallel Virtual Machine) [5].

Microcomputers, which are increasingly used for cluster realization, typically have standard communication interfaces, including the ability to connect to different types of computer networks. One of the most famous modern microcomputer families on one board is the Raspberry Pi family [6]. The latest generation of these microcomputers, Raspberriy Pi 3, have the following features:

- CPU: Quad-core 64-bit ARM Cortex A53, 1.2GHz
- GPU: 400MHz VideoCore IV multimedia
- Memory: 1GB LPDDR2-900 MHz SDRAM
- USB: 4 ports
- Video outputs: HDMI, composite video (PAL and NTSC)
- Network: 10/100Mbps Ethernet and 802.11n Wireless LAN
- Peripherals: 17 GPIO, HAT ID Bus
- Bluetooth: 4.1
- Power source: 5V via MicroUSB or GPIO header.

Fig. 1 shows the appearance of Raspberry Pi 3 module.

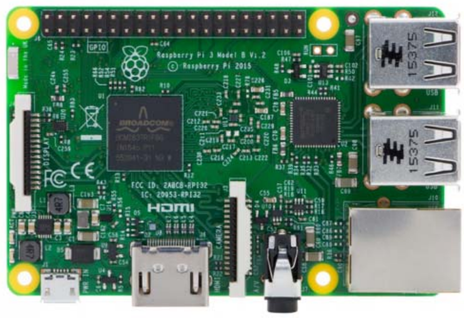

Fig. 1. Raspberry Pi 3 module

Thanks to the processor and memory characteristics and the ability to connect to the Ethernet network, Raspberry Pi modules are a good basis for the development of an appropriate computing cluster. The aim of this paper is to show the possibilities of practical use of the computer cluster.

THE CONCEPT OF A COMPUTER CLUSTER

By the term computer cluster are defined several interconnected computers, and according to the outside world they behave as a unique device. Computer cluster members are called nodes, and one cluster can contain from two to several hundred nodes. Nodes are most often connected through a faster local network, and the degree of connectivity depends on the connection method [7] – [9].

The main advantages of using computer clusters are higher processing speeds, flexibility and availability of

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resources. One of the most well-known clustering systems is the Beowulf Cluster [10], [11].

Fig. 2 shows the basic structure of the computer cluster [12]. Computers within a cluster are connected to a local computer network. Compute Nodes are computers running parallel software. Head Node indicate the computer through which the cluster is connected to the environment. The cluster configuration in Fig. 2 is sufficient to support inexpensive calculations [13] – [15]. Accordingly, it can be realized using Rasperry Pi 3 modules.

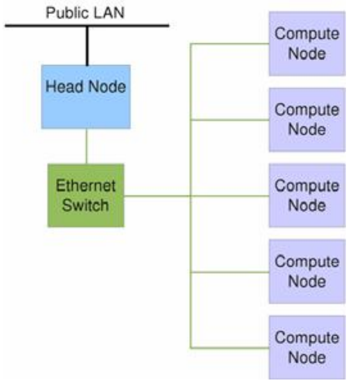

Fig. 2. Typical structure of MPI cluster [12]

This paper deals with the possibilities of using clusters realized using four Raspberry Pi modules.

COMPUTER CLUSTER VIRTUALIZATION

Computer cluster enables parallelism in the processing, so the complex computations can be done in significantly shorter time [16] – [18]. Beside physical clusters, it is possible to realize virtual clusters that are built on virtual machines. These virtual machines are deployed on distributed servers with one or more physical clusters, while being interconnected via virtual network surrounding multiple physical networks.

The advantage of virtual clusters is very fast deployment of all the necessary cluster elements in the virtual surrounding. Beside easier implementation, the clusters based on virtualization have greater possibilities in load balancing executing applications. The load parameters can be tracked by end users and based on their values, the automatic mechanism of virtual cluster resources management is triggered [19].

By interconnecting multiple Raspberry Pi devices into one local network, a basis is found that is later transformed into cluster. It is necessary to enable message passing and implement software support for task management. Software support is deployed both on the head node and compute nodes, while the program intended for execution is divided in parts that are supposed to be executing separately on head node and on compute nodes. The head node performs task management to the existing units in the cluster and after that, the results are returned to the head node [20].

In order to facilitate loading new programming code that should execute in parallel on the cluster, the system can be accessed remotely via web interface. In this way, the remote access to the cluster is enabled with the possibility of loading programming scripts that perform some calculations.

The user can load his code into head node, and then copy the client section of the code to all the client nodes in a cluster. When all the program parameters are set and ready, the main program on the head node is started. After the calculations are over, the results that parallel program produces are on the head node and can be easily transferred via web interface.

In this way, we can form a cluster with appropriate size and with current financial limitations and needs. The cluster can be upgraded in the future by simple addition of new computing nodes in order to conform to the new demands. Beside accessibility to the researchers, the students can also review the cluster infrastructure and the whole process of the parallel code execution.

PRACTICAL EXAMPLE OF THE RASPBERRY PI CLUSTER VIRTUALIZATION APPLICATION

In order to demonstrate the application of the Raspberry Pi cluster virtualization, we implemented cross-correlation function in Python. This function gives the similarity of two items. It is calculated as inverse Fourier transform of the product of the two Fourier transformed functions. We used cross-correlation to compare two images for similarities, as shown in Fig. 3.

Fig. 3. Cross-correlation as the similarity measure

The program for cross-correlation is written in Python. Two versions of the program were executed, sequential and parallel. Both of them are using methods from Python libraries numpy, skimage, and scipy.

The parallel version of the code defines two variables for defining number of images to be processed and number of processor cores in use. The sample program section is given below.

```
for IMAGES in 108 216 432; do
    for CPU in 4 7 10 13; do
        mpiexec -f machinefile -n $CPU
python /home/pi/mpi4py-2.0.0/demo/images
gift.py $IMAGES >> mpi$CPU.$IMAGES.log
    done
done
```

As can be seen from this code snippet, MPI library was used to implement parallelism on the cluster. Every node is given his own portion of the image-processing task. When all the nodes finish the processing of the images, they send the results to the head node. The head node collects results, forms the final cross-correlation matrix and displays it as a final solution.

CONCLUSION

The development of computer clusters has become particularly interesting with the advent of computer modules such as Raspberry Pi and BeagleBone. The excellent process and communication characteristics of these modules allow the development of computer clusters whose nodes are based on these modules. Cluster realization based on four Raspberry Pi modules created conditions for research in the field of practical application of clusters in solving complex calculation problems.

The presented example of calculating the cross-correlation is a confirmation of the practical capabilities of the considered computer cluster based on Raspberry Pi modules. Also, the concept of access to the cluster via the Internet further expands the possibilities of practical application of the developed cluster.

With this in mind, a significant part of the research in the field of computer clusters, conducted in the Computer Science Laboratory, will be dedicated precisely to the realization of support for cluster access through the Internet, as well as further research in the fields of parallel and distributed computing.

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