COMPUTER SIMULATION OF MIMA ALGORITHM FOR INPUT BUFFERED CROSSBAR SWITCH

Tasho Tashev, Tatiana Atanasova

Abstract: The investigations for throughput of a new algorithm for computing of non-conflict schedule in crossbar switch node are presented in this paper. By means of Generalized nets (GN) a model of MiMa (Minimum from Maximal Matching) algorithm is synthesized. The results of computer simulation of a GN-model performing uniform load traffic are presented. Evaluated throughput of the switch mode tends near the 100% and no regions of instability are detected.

***Keywords**: Modeling, Generalized Nets, Communication Node, Crossbar Switch, Algorithm, Simulation.*

***ACM Classification Keywords**: B.4.4 Performance Analysis and Design Aids, C.2.1 Network Architecture and Design, C.4 Performance of Systems*

Introduction

At present, digital telecommunications streams are based on the exchange of packets. In information exchange networks the essential nodes are commutation nodes called switches and routers. Crossbar packet switches route traffic from input to output where a message packet is transmitted from the source to the destination.

The randomly incoming traffic must be controlled and scheduled to eliminate conflict at the crossbar switch. The goal of the traffic-scheduling for the crossbar switches is to minimize packet blocking probability and packet waiting time and to maximize the throughput of packet through a switch [Elhanany, 2007]. So achieving a maximum throughput of the switch depends on the calculation of non-conflict plan for switching incoming packets.

The problem for calculating of non-conflict schedule is NP-complete [Chen et al, 1990]. Algorithms are suggested which solve the problem partially. Constantly rising levels of traffic communication require developing of new, more efficient algorithms for calculating the schedule.

The origin of a series of parallel algorithms is the PIM-algorithm (Parallel Iterative Matching) [Anderson et al, 1993]. One of the research directions is working on modifications to PIM-algorithm, relying on input buffering with virtual output queuing (VOQ) [Guannan Qu et al., 2010]. Other studies are directed to the use of inputs and intermediate buffering (CICQ) [Dinil Mon Divakaran et al., 2010]. The approach with an intermediate load balancing also attracts attention. Of course, research is also directed towards a fully optical switching [Lin Liu et al., 2010].

Cellular automata, neural networks, etc. are used as formal means to describe and study the characteristics of crossbar switch nodes. In this investigation the apparatus of Generalized Nets (GN) are used as a powerful modern tool for formal modeling of parallel processes. Generalized nets (GN) [Atanassov, 1991, Atanassov, 1997] are a contemporary formal tool created to make detailed representation of connections between the structure and temporal dependencies in parallel processes. They are used in different fields of application, telecommunication is one of them [Gochev, 2008], [Tashev and Gochev, 2009]. The apparatus of GN in this research is applied to synthesize a model of one new algorithm for computing of non-conflict schedule in the crossbar switch node.

In this paper we presented the investigations on the proposed new algorithm for crossbar switch - MiMa (Minimum from Maximal Matching) algorithm. The algorithm is design to calculate a non-conflict schedule in crossbar switch node with VOQ. It is based on a new criterion for selecting of non-conflict solutions. Checking of its applicability is done by computer simulation of switching of these non-conflict solutions through synthesized Generalized-Nets based model of the MiMa algorithm. Its assessment is based on the modeling firstly of the throughput in the presence of uniform distributed incoming traffic. For this purpose, four templates are used to simulate uniform demand traffic and the evaluation of the performance of the MiMa algorithm has been obtained.

Algorithms of Non-Conflicts Schedule for Commutation

The requests for transmission through switching n x n line switch node is presented by an $n \times n$ matrix T, named traffic matrix (n is integer). Every element t_{ij} ($t_{ij} \in$ [0, 1, 2, …]) of the traffic matrix represents a request for packet from input i to output j. For example t_{ij} = 2 means that two packets from the i^{-th} input line have to be send to j^{-th} output line of the switch node, etc.

It is assumed that a conflict situation is formed when in any row of the T matrix the number of requests is more than 1 – this corresponds to the case when one source declares connection with more than one receiver. If a column of the matrix T hosts more than one digit 1, it indicates a conflict situation. Avoiding conflicts is related to the switch node efficiency [Elhanany, 2007].

In our previous investigations algorithms for computing of non-conflict schedule are modeled by Generalized nets based on the principle of sequent-random choice [Tashev and Vorobiov, 2008].

The new developed MiMa algorithm also is based on the principle of sequent-random choice, but it uses a new criteria. Its informal description is as the following:

Matrix T is introduced. A vector-column, which consists of the number of conflicts in which row (conflict weights) is calculated. A vector-row, which consists of the number of conflicts in each column (column weight), is calculated too. In the vector-row we choose the maximal element (the column with the most conflicts). In the vector-column we choose the maximal element (the row with the most conflicts). If there is a request in the place of intersection in T we take it as an element of the non-conflict matrix Q_k. If not – we choose the element in the vector-column following the maximal element. We check if there is a request, etc. As a result for the chosen column of T we will choose a request (if indeed it exists) and we will reduce the weight of conflict of the corresponding row and column. We take the element following the maximal element in the column and we search for a request for it using previously described criteria. As a result the first matrix Q_1 will consists of elements (requests) with maximal weight of conflicts in T. For the last matrix Q_k it will be left only non-conflict requests in T.

Generalized Net Model of MiMa-Algorithm

The algorithm MiMa can be described formally by the means of Generalized Nets. The model is developed for switch node with *n* inputs and *n* outputs. Its graphic form is shown on Figure 1.

The model has possibilities to provide information about the number of switching in crossbar matrix, as well as about the average number of packets transmitted by one switch. Analysis of the model proves receiving a non-conflict schedule. Calculation complexity of the solution depends on the power of four of the dimension *n* of the matrix T $(O(n^4))$. Numerical modeling should provide us with the answer to the question: do we have a better solution with this algorithm or not in comparison with existing ones?

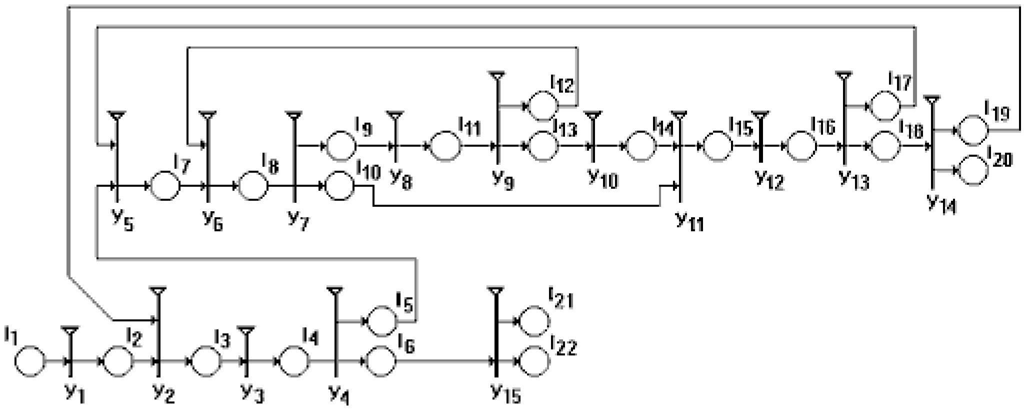

Figure 1: Graphical form of GN-model of MiMa-algorithm

Computer Simulation

The transition from GN-model to executive program is performed as in [Tashev and Vorobiov, 2007]. The program package Vfort of Institute of mathematical modeling of Russian Academy of Sciences is used [Vfort]. The source code has been tested and then compiled by the PC with Intel E8400 2x3.0 GHz, 2 GB RAM. The resulting executive code is executed in the DOS-console under Windows XP SP2. Main restriction for the choice of parameters in simulation (dimension *n* and type of load traffic) is the time for execution of the program.

Achieving maximal throughput of crossbar switch node depends on creation of non-conflict schedule for packet commutation. The first step while checking their efficiency is throughput modeling of the switch by uniform demand traffic. The matrix *T* defines a uniform traffic demand matrix if the total number of packets in each row and that of each column are equal [Gupta and McKeown, 1999].

The uniform demand traffic matrix is called in the investigation as $Pattern_i$. The index *i* shows values of element in the traffic matrix. All elements in the traffic matrix are equal. This allows calculating the throughput because in this case an optimal solution is known. The throughput is computed by dividing the result of optimal solution on the result of the simulated solution. The result of algorithm is a number of non-conflict matrices. Their sum is equal to *T*, as number of matrices shows number of commutations.

Figure 2 presents the used input data – *uniform matrix T*, defined by us. The first type of the matrix is called $Pattern_1$. Its specification is shown on the left of the figure 2. The optimal schedule requires *n* switching of crossbar matrix for *n* x *n* switch. The second type of the matrix is called *Pattern$_i$*. Its specification is shown on figure 2 (right). The optimal schedule requires (*i* x *n*) switching of crossbar matrix for *n* x *n* switch.

$$T=\underset{2\times 2}{\begin{bmatrix}1&1\\1&1\end{bmatrix}}\ \underset{3\times 3}{\begin{bmatrix}1&1&1\\1&1&1\\1&1&1\end{bmatrix}}\cdots\underset{k\times k}{\begin{bmatrix}1&\cdots&1\\\vdots&\ddots&\vdots\\1&\cdots&1\end{bmatrix}}\cdots\qquad T=\underset{2\times 2}{\begin{bmatrix}i&i\\i&i\end{bmatrix}}\ \underset{3\times 3}{\begin{bmatrix}i&i&i\\i&i&i\\i&i&i\end{bmatrix}}\cdots\underset{k\times k}{\begin{bmatrix}i&\cdots&i\\\vdots&\ddots&\vdots\\i&\cdots&i\end{bmatrix}}\cdots$$

Figure 2: Types of the uniform traffic matrix T

The results from the computer simulation of the MiMa-algorithm with input data *Pattern$_1$* and *Pattern$_5$* are displayed on figure 3 and 4. The crossbar matrixes of the size 2x2 up to 130x130 are simulated. The results of simulations with input data *Pattern$_{10}$* and *Pattern$_{50}$* are demonstrated on figure 5 and 6. It can be seen that when the size of *Pattern* and dimension of switch field increases, the throughput asymptotically tends to 100%.

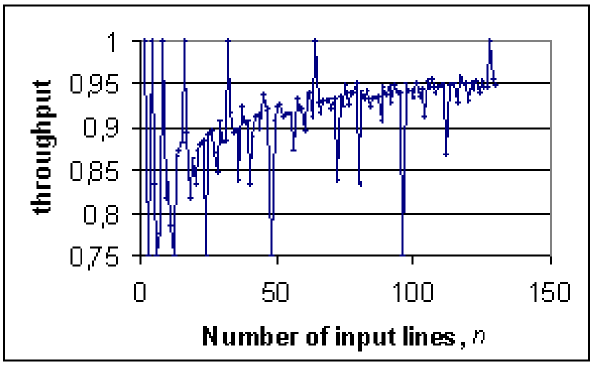

Figure 3: Throughput with Pattern$_1$

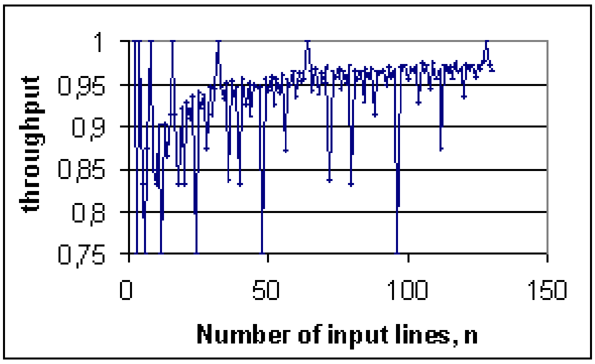

Figure 4: Throughput with Pattern$_5$

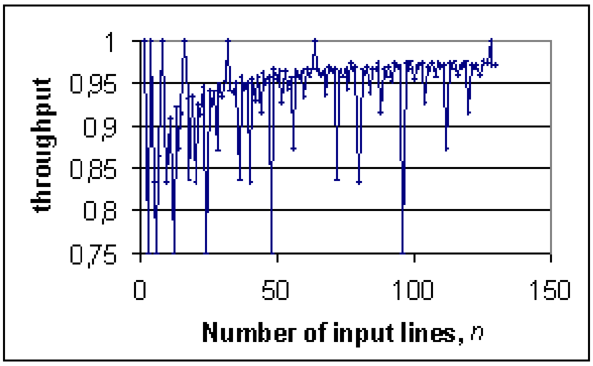

Figure 5: Throughput with Pattern$_{10}$

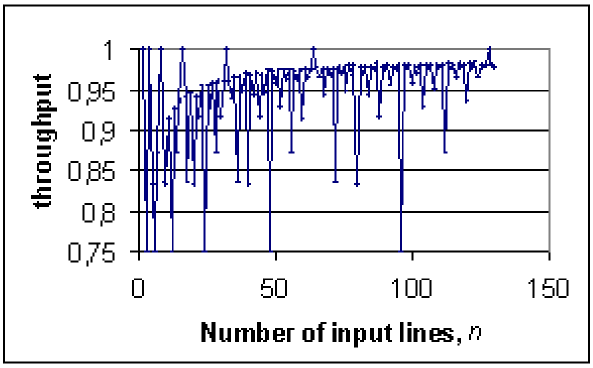

Figure 6: Throughput with Pattern$_{50}$

Evaluation of the simulation results illustrates that MiMa algorithm has low sensitivity to the increasing of input buffer. Figure 7 gives evidence for the difference between throughput in cases of *Pattern$_{50}$* and *Pattern$_1$* – when input buffer increases in 50 times. The difference between throughput in cases of $Pattern_{50}$ and $Pattern_{10}$ is shown in figure 9 (increasing 5 times).

For checking existence of regions of instability we used a version of $Pattern_1$, in which the main diagonal consists of elements equal to zero (called $Pattern_{1-0}$). Figure 9 shows throughput for this case. The differences between throughput from figure 1 and figure 9 tend to zero. This result is summarized on figure 10.

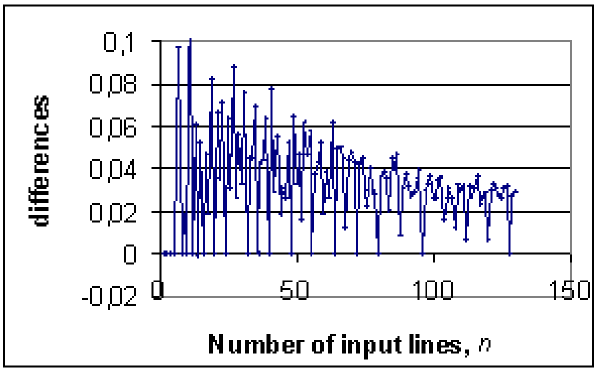

Figure 7: Differences between throughput P_{50}-P_1

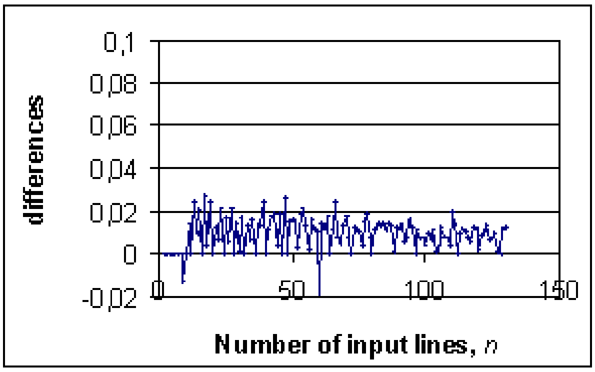

Figure 8: Differences throughput P_{50}-P_{10}

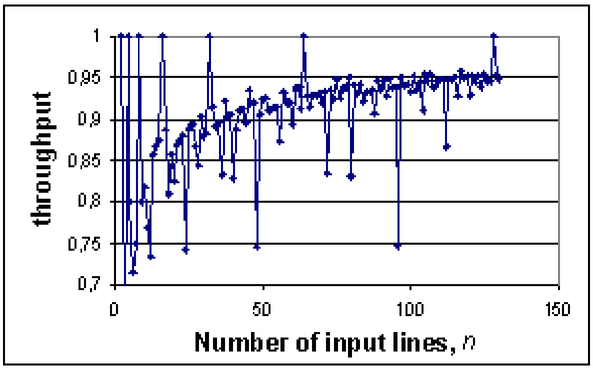

Figure 9: Throughput with $Pattern_{1-0}$

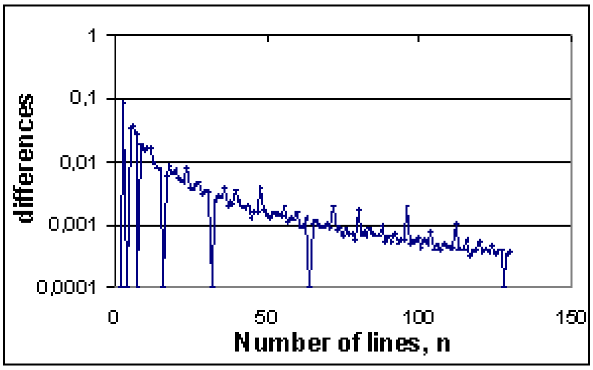

Figure 10: Differences between throughput P_1-P_{1-0}

We specified the family of variants of $Pattern_i$, in which the main diagonal consists of elements equal to zero (called $Pattern_{i-0}$). The cases of $Pattern_{5-0}$, $Pattern_{10-0}$ and $Pattern_{50-0}$ were also checked. The results are similar – they show absence of instability.

The promising results from the simulation on the MiMa algorithm lead us to an idea of conducting of large-scale simulations for non-uniform demand traffic that can be direction for the future work.

Conclusion

In this paper the investigations on new algorithm for calculating a non-conflict schedule for crossbar switch node are presented. Computer simulations of a Generalized Nets-based model of MiMa-algorithm performing uniform load traffic have been carried out. The results of simulation are evaluated. The simulations illustrate that MiMa algorithm has low sensitivity to the increasing of input buffer. It is shown that throughput of switch mode asymptotically tends to 100% under uniform traffic and no regions of unstability are detected.

Future work should be directed to carrying out large-scaled computer simulation to study the throughput for large dimensions of the switching field and a wide range of incoming demand traffic. The opportunities to parallelize the proposed algorithm could be searching for.

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Authors' Information

Tasho Tashev, *Department "Optimization and Decision Making", Institute of Information and Communication Technologies – Bulgarian Academy of Sciences*, *“Acad. G. Bonchev” bl. 2 Sofia 1000, Bulgaria; e-mail:* *ttashev@iit.bas.bg*

Major Fields of Scientific Research: Distributed Information Systems Design, Methods and tools for net models researches

Tatiana Atanasova, *Department "Optimization and Decision Making", Institute of Information and Communication Technologies – Bulgarian Academy of Sciences*, *“Acad. G. Bonchev” bl. 2 Sofia 1000, Bulgaria; e-mail*: *atanasova@iit.bas.bg*

Major Fields of Scientific Research: Complex Control Systems, Learning Structures, Distributed Information Systems